3. RESEARCH SUPPORT FACILITIES

3.1 SUPPORT LABORATORIES

3.1.1 High vacuum laboratory

Chandra Pal Maurya, A. Kothari, P. Barua and S. Chopra

High vacuum laboratory is primarily responsible for maintaining vacuum and vacuum systems in beamlines and experimental facilities. It provides support to different labs and users in vacuum related problems. Vacuum lab is also involved in the installation and commissioning of various beamlines, experimental and accelerator facilities at IUAC. High Current Injector [HCI] installation is in progress and installation of LEBT components has been completed. All the LEBT components have been interfaced with VME control system and can be controlled through remote control console. HIRA beamline and experimental facility got misaligned due to sagging of the floor around the beamline. Consequently, alignment offset of the components were measured and corrective action was taken to restore the correct position of the components.

3.1.1.1 Installation of High Current Injector (HCI), Low Energy Beam Transport (LEBT) section up to RFQ

Chandra Pal, Ashok Kothari, P. Barua, Y. Mathur, U.K. Rao G. Rodrigues, R. Ahuja, D.K. Munda, Kundan Singh, S.K. Suman, Mukesh Kumar, Sarvesh Kumar, Kusum Rani, Rajkumar, A. Mandal

The installation of HCI continued this year and the remaining LEBT components have been installed in the beamline. The pointwise summary of the same is given below.

- **Diagnostic Units:** Two beam diagnostic units have been made consisting of a NEC BPM module and pair of NEC beam slits assembled onto newly designed vacuum chambers. These diagnostics would be used for pre and post bunched beam diagnosis.

- **Vacuum Pumping Chamber:** A new vacuum pumping chamber has been designed and fabricated and it is installed with 1000 lps maglev turbo pump. A Danfysik make water cooled insertable Faraday cup is also mounted on DN 100 CF port on chamber top.

- **Fast Faraday Cup (FFC) chamber:** A vacuum chamber for the installation of Fast Faraday cup has been designed and fabricated. FFC sits on the top DN 150 CF tapped flange and a port on the side is provided for installing a 600 lps turbo pump. A linear motion feedthrough with an aperture ladder is also installed on a DN 40 CF port towards RFQ side. The aperture protects the RFQ vanes during tuning of beam.

- **Magnetic Steerers:** A pair of magnetic steerers have been designed and fabricated for installation within the quadrupole, for beam correction.

- **Quadrupole:** It consists of four singlet quadrupoles and for the installation and alignment of these quadrupoles a mounting fixture has been designed and fabricated. All the four singlets are mounted on a single base plate with provision for individual alignment of each of them. A vacuum chamber for the quadrupoles was also made with two edge welded bellows at the ends to provide flexibility in installation within the limited space. Two magnetic steerers have also been installed within the available spaces between singlets, as shown in figure 3.1.1.

- **Multi Harmonic Buncher (MHB):** It has been installed with a newly made alignment and mounting fixture. An ion pump (400 lps), with a gate valve, is also mounted on the side port of the buncher chamber. Because of the gate valve the ion pump runs continuously uninterrupted during venting of the chamber. BPM-Slit diagnostics are also installed at the entry and the exit of MHB.

- **RFQ** has been perfectly aligned within 0.5 mm of beam axis, as shown in figure 3.1.2.

- All the components are mounted firmly on a stand made of standard aluminum profiles assembled and erected as per component load positions, available space and ease of installation. All the critical ports, for BPM, slits, aperture etc., in the vacuum chambers are fabricated within an accuracy of 0.5 mm. The components are aligned within 0.5 mm of beam axis. A compact diagnostic box, consisting of BPM-Faraday cup assembly, is installed at the exit of RFQ for post acceleration beam diagnostics. We have achieved an ultimate vacuum of 5.0×10^{-10} torr with two turbo pumps of capacity 1000 lps and 600 lps and an ion pump of 400 lps, installed in the LEBT section.

- All beamline components (FFC, Faraday cup, BLV, steerers, quadrupoles, etc.) of this section are controlled by VME based control system. These components have been interfaced with the VME control system and all control and status read signals are available on the remote control console. Digitized BPM signals from the high voltage platform have been provided in the control console through BPM digitizer. All other BPM signals have also been brought in the control console.

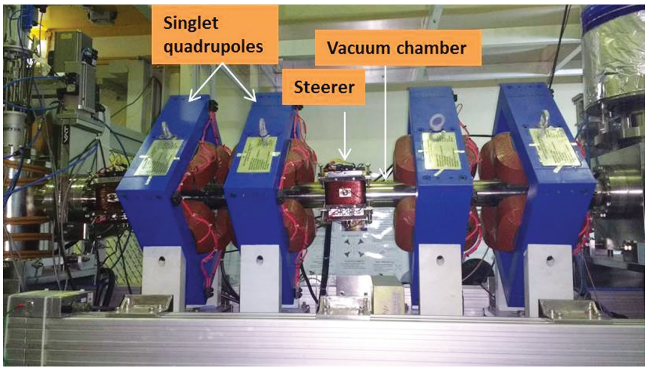

Figure 3.1.1. Quadrupole Singlets of LEBT section

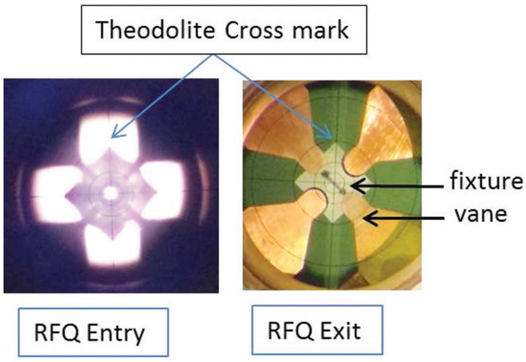

Figure 3.1.2. RFQ Alignment

3.1.1.2 Alignment Correction in HIRA beamline and HIRA Experimental set-up

Chandra Pal, A. Kothari, P. Barua, J. Gehlot, T. Varughese, S. Nath, N. Madhavan

It was observed that extremely high values of magnetic field were required in the HIRA beamline magnetic steerers during beam run in HIRA. During maintenance of Pelletron, alignment of different components of HIRA was measured with respect to analyzer and switching magnet of vault I. It was found that alignment with respect to the height of analyzer and switching magnet of vault I, Beamline Quadrupole and experimental chamber were down by 25 / 30 mm and slightly offset towards right. Similarly, the magnets on the HIRA platform were down by 20 mm to 38 mm with respect to beam axis. The reason for the same appears to be sagging of floor in this area due to presence of dense shielding wall (hundreds of tons of haematite bricks weight) near that area. Cracks between the wall (common to vault I and beamhall I) and ceiling are also clearly visible supporting the same. The correction in the alignment of beamline components was done first. Beamline components alignment was rectified as given below.

- Packing plate was fabricated for raising these components
- Beamline Components i.e. Quadrupole, BPM 1, BPM 2, BLV L3_2 – raised by 25 mm.
- Alignment of these components done within ± 1 mm.

HIRA Platform Height Correction: HIRA setup consists of big platform measuring 8.8 m by 2.5 m in size and it is supported at three points. One support is pivoted and the platform move in angular motion about the pivot, supported on wheels at the other two supports. Four big magnets are installed on the platform along with the spectrometers. The total load of the platform along with all the onboard components is approximately 18 tons. Due to sagging of the floor the magnets position had shifted down by 20 to 38 mm with respect to beam axis. As it is a heavy load it's correction of height had to be carried out carefully. First the measurement of alignment mismatch was done for each magnet and at different angular position of the platform. It was found that the magnet (positioned near the beamline) was down by 38 mm and the magnet towards the wall was down by 20 mm. As the platform was supported on three points, the lifting of the same had to be done from there only. Accurate measurements were taken and packing flange and plates for the three supports were designed and fabricated. Lifting was done gradually in small steps using heavy duty mechanical jacks and simultaneously monitoring the height displacement using dial indicators, which were put at different points. Plumb points from the platform sides were marked on the floor for restoring exact angular position after the lifting process. The magnets positions after height correction are now within 1.5 mm of the beam axis and the original angular position is also restored.

Modification of the HIRA beamline in experimental area: The beamline has been modified by replacing the older stands by stands made from aluminium profile. BPM, Faraday cup, beamline valve and the pumping cross have been reinstalled and aligned with the beam axis. Experimental area cable connections for signal and power have been restored.

3.1.1.3 Maintenance Activities

- BPM 02-1: BPM of 02 area had stopped working, it was made functional by replacing its head assembly.
- Ion pump maintenance: Ion pump 04 had stopped working and after investigation leak was found in high voltage feedthrough. It was replaced with a cleaned ion pump. Ion pump of switching magnet 1 was found electrically short so it was also replaced with a cleaned pump. Ion pump 07-1 was electrically short so it was dismantled, cleaned, baked and normal functioning was restored.
- Getter pump maintenance: Getter pumps of HIRA beam line and 07 area were cleaned and cartridges replaced.

3.1.2 Cryogenics and Applied Superconductivity Laboratory

Anup Choudhury, Joby Antony, Suresh Babu, Manoj Kumar, Soumen Kar, Santosh Sahu & T S Datta

3.1.2.1 LHe plant operation

(A) Helium plant operation and upgradation

The machine was operated for 7 times (run no. 13 – run no. 19). Most of the run was dedicated for offline cavity tests in STC (21 total number of tests were carried out in STC for performance measurement of the cavities made/rectified recently), but some amount of time was dedicated for LINAC test as well without beam. The online tests were carried out on LINAC1 and LINAC2 after unscheduled maintenance activities in them. During this period, slow tuner electronics was tested in the LINAC 1 and new cavities which were installed in LINAC2 were tested.

Run no.	Hrs on compressor	Cumulative hours	Usage
13-19	9480-13034	3554 hr	21 cavity test, 1 magnet coil test and 1 MRI joint test

Each cavity tests takes around 4-5 days for completion and a gap of 2-3 days before the loading of the next cavity. So it was decided to go for cold mode of operation of helium plant where the liquid is produced for 2 days during the cool down of the cavity and for rest of of the days only the compressor runs and turbine remains non-operational. When the new cavity is loaded the turbines are again started after proper purification of the cold box. It takes around 3-5 hrs for liquid helium to start filling up the main dewar again. This mode of quick start up operation of cold box turbines along with fast warm up operation of the cavity inside the STC has helped to conduct 21 nos of tests in such a short time. The outcome of the tests has helped LINAC group to identify dress up parameters before loading the cavities to the main cryostat. From cryogenic point of view this development has helped us to run the system in this mode for long haul operation.

There has been some upgradation or alteration of the helium infrastructure in this academic year which has helped to achieve this goal. They are mentioned below:

- **Liquefier support infrastructure upgradation:** The chilled water supply to the compressor has been completely augmented hereby the secondary pump in the loop and the 3rd phase chiller plant has been given the generator power. The two air compressors which were earlier not connected to the generator has been hooked up to it. Also there has been a thorough leak check of the air lines which has revealed a lot of losses at various positions, which has been rectified.
- **Shifting of helium purifier:** The external helium purifier connected to LINDE plant in the compressor room (412) was shifted near the cold box and new LN2 feed line from the existing distribution line network was connected to it. With this shifting the purifier can be operated by a single person without any other help.
- **Helium impurity monitor:** The impurity meter (Gow-Mac, USA) for detecting the ppm level nitrogen in helium has been replaced with the indigenous impurity detector due to erroneous reading reported from the detector. The backend electronics has been upgraded with addition of active noise suppression and scaling of the meter with standard gas. This system is now a full time part of the machine and all our operational decision is based on the value readings from the same.

(B) Cryogenic distribution infrastructure improvement

- LHe distribution line leak fixing: The liquid helium distribution system has the largest volume in a single vacuum environment in the whole of cryogenic infrastructure. Over the years of its operation due to slow deteriorating vacuum we have connected two no of 250 lps turbo pump to the infrastructure and despite that the vacuum in helium condition was deteriorating. A detailed leak profile of the entire system undertaken revealed that there have been active vacuum leaking ports mostly the pump out ports in all four valve boxes. These leaking ports were replaced with a KF coupling and at two positions the vacuum gauges were connected. The vacuum in the cold condition of the cryostat has improved at least 1 order of magnitude.
- **LINAC Cryostat improvement:** All the three LINAC cryostat have a significant heat load and they are of the order of 60-80 watts. On analyzing the design it was noticed that the side copper shield was almost 150 mm down from the top shield and also the turbo pump port was open. We covered the openings with a 2.2 mm thick copper sheet in all 4 sides and the top holes are been plugged partially with aluminum tape. A total of ~0.5 m^2 area has been covered in LINAC 2 and LINAC 3 cryostats and 0.3 m^2 in rebuncher cryostat. This effort shall certainly reduce heat load coming to the cryostats.
- **GN2 return line and other LN2 line upgradation:** Cold nitrogen gas returning from the cryostats was warmed up by passing it through a bare pipe. To avoid the water dropping a complete vacuum jacketed pipeline 35 meter long vacuum lines has been procured from Demaco and put in place. This line will help us to reduce the water dropping in the existing line and also reduce the operating pressure inside the cryostat.

(C) Developmental activities

Cryocooler liquefier development :- A helium liquefier using a 1.5 watt at 4.2K Gifford-McMohan (GM) cryocooler was developed at IUAC having a liquefaction capacity of 17.4 litres per day (lpd) at STP. This standalone setup could not be used for any other experimental facility which requires liquid helium for its functioning and so another portable experimental liquefier was designed and fabricated using the same technology, which can be used to hook up the liquefier easily using their liquid inlet line port. In the present experimental demonstration setup, the cryocooler liquefier was hooked up to a commercial 100 lts helium dewar. The dewar was cooled starting from room temperature with the cryocooler liquefier in 2 days and 50 litres of liquid helium was collected inside the dewar. The measured production rate of liquefaction was 14.2 lpd. Successful liquefaction of helium in such a portable setup opens up the door for using this technology for other experimental purpose requiring liquid helium.

3.1.2.2 Electronics for Cryogenics, Applied Superconductivity and LINAC

Joby Antony, D.S. Mathuria, Anup Choudhury, Soumen Kar, T.S. Datta

A. Cryogenic controls

The IUAC Cryogenics control room was inaugurated in the year 2002 and has been operational for last 15 years. This year the control room has been renovated to a new look and has an added big wall-mounted 22 inch monitor for projection of control network screens. Presently the control room has three control consoles, namely CADS, CRYO-DACS and LINDE PLANT CONTROL CONSOLE; all of them are controlled through cryogenic LAN.

CADS

The successful Ethernet based Crate-less model of completely indigenous Cryogenic control hardware and software, built out of in-house designed intelligent cryogenic instruments, interconnected over Ethernet(LAN) with on-chip http servers has been operational for last five years(24x7) in continuous mode. This model is proven to be having certain advantages over conventional crate architectures and is a rugged design for Cryogenics distribution system with minimum component failures for last six years. Network analysis, a qualitative test is also performed using WIRESHARK to measure the network traffic and has been found to be a low-bandwidth control network. CADS instruments which were originally designed as device-sensor-servers have been compatible to Internet of things too.

CRYO-DACS

The second system, CRYO-DACS, a VME system which was installed in the year 2002 for all linac temperature monitoring, is still operational. Now the VME system is used only for temperature monitoring of LINAC parameters and rest has been ported to new CADS system.

All important signals from CADS and CRYO-DACS systems have been now grouped and brought together to a central interface-device through analog buffers to tap the most important 35 signals of cryogenics network to IUAC linac control network. The interface device is shown below in Fig 3.1.3.

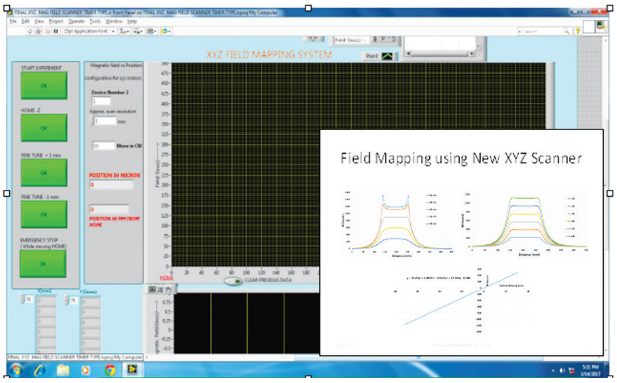

Fig 3.1.3: Interface box

Fig 3.1.4: Field Mapping software

Table 1: Comparison of imported Unit & IUAC built one

Parameters	Imported unit	IUAC device
1. Control accuracy	+/- 0.25 torr in 100 Torr	+/- 0.010 Torr in 100 Torr
2. Control loop timing	0.05 sec 10 sec	Any value digitally programmable
3. Remote Control	No digital I/F	USB & Ethernet
4. Control Loop PID Loop PID setting	MANUAL POTS where accuracy suffers	AUTOMATIC/REMOTE PROGRAMMED
5. Repeatability	Analog type -not that good	Very good as it is digital
6. Production	N/A	Easy as it needs no retuning
7. Cost	High	Cheap
8. Custom interlocks	Not possible	Possible
9. Display	Small	Big displays to update all information

B. Development activities

Field Mapping System -Windows PC based
Joby Antony and Sarvesh Kumar

Users demanded a PC based XYZ file mapping system to be developed as PC's are more user friendly to record data directly in EXCEL format. The Graphical user interface was developed using LabView® as user's preference as shown in Figure 3.1.4. A daisy chained ALST model (M/s Zaber Technologies) fitted with three Stepper motors are interfaced with PC through RS232 for the X-Y-Z movement. A Hall probe paired with a Digital Tesla Meter is used for accurate magnetic field measurement.

A PID based gas flow processor unit
Joby Antony, Rajesh Nirdoshi, N. Saneesh, P. Sugathan

Regulated flow through a detector system (0.0 to 99.99 Torr) with accuracy of the order of +/- 10 milli Torr, Digital PID implementation with various interlocks is tried out successfully. More units are in demand as it outperformed the imported units in tests. In its next phase, Computer software interface and modified firmware is planned to be implemented on request of user requirement in NAND.

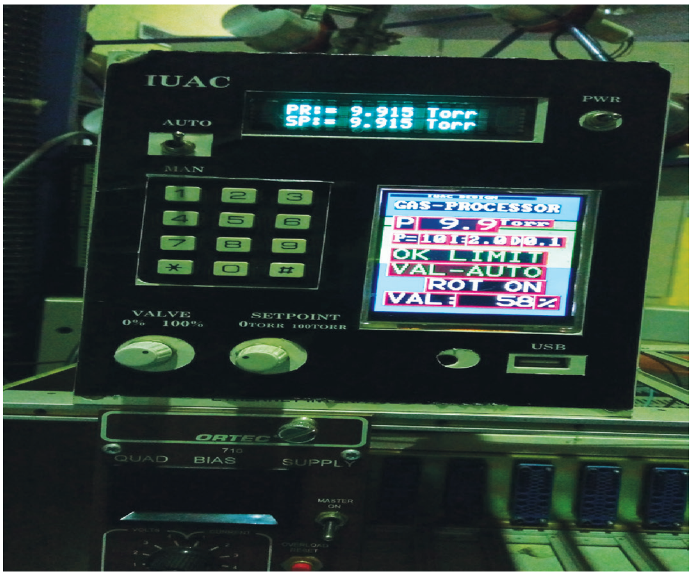

Fig.3.1.5 The device front panel

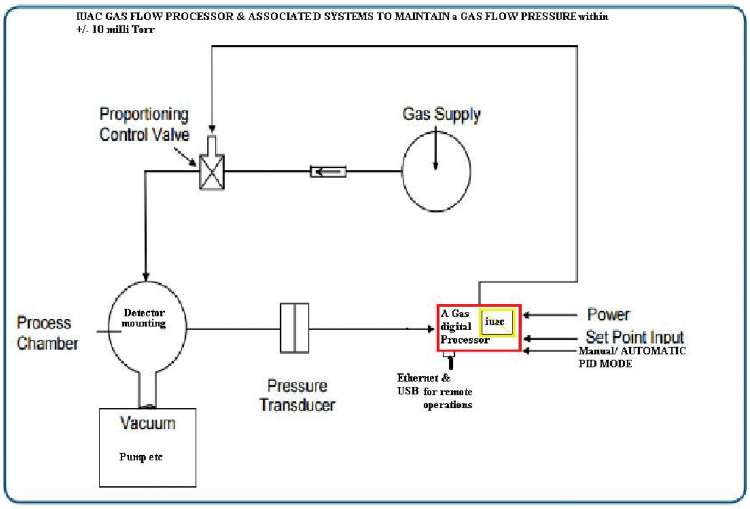

Fig 3.1.6. Block diagram

The above figures show the front panel of this device (fig.3.1.5), its block diagram (fig.3.1.6) and its comparison with similar imported units as shown before in Table 1.

A Special Switch matrix designed for LowTc Lab

Joby Antony, A.K. Rastogi, K. Asokan

A device which can have multiple combinations of Relay switches, viz.1,2,3,4 to be interconnected from experimental samples inside cryostat, which is useful for LowTc lab has been designed and delivered.

The Special switch matrix has been designed to follow the following truth table of I/V four probe measurement as shown in figures.(fig 3.1.7 & 3.1.8)

Fig. 3.1.7 Special switch matrix

I+	I-	V+	V-
1	2	3	4
1	4	2	3
2	3	1	4
3	4	1	2
1	3	2	4
2	4	1	3

Fig. 3.1.8 Truth table

Impurity monitor- device
Joby Antony and Anup Choudhury

A digital device (Fig. 3.1.9) which digitizes very noisy low millivolt sensor voltages, coming out of IUAC built Nitrogen impurity sensor developed by Anup Choudhury, is designed to digitally filter and implement a transfer function to display it as Nitrogen impurity levels in ppm. This is tested successfully and is put to use along with cryogenic plant control/monitor operations. A current linearizer of 4 to 20 mA is also built along to feed signals to LINDE-control system to view and analyse data on 24 hr. basis (fig. 3.1.10).

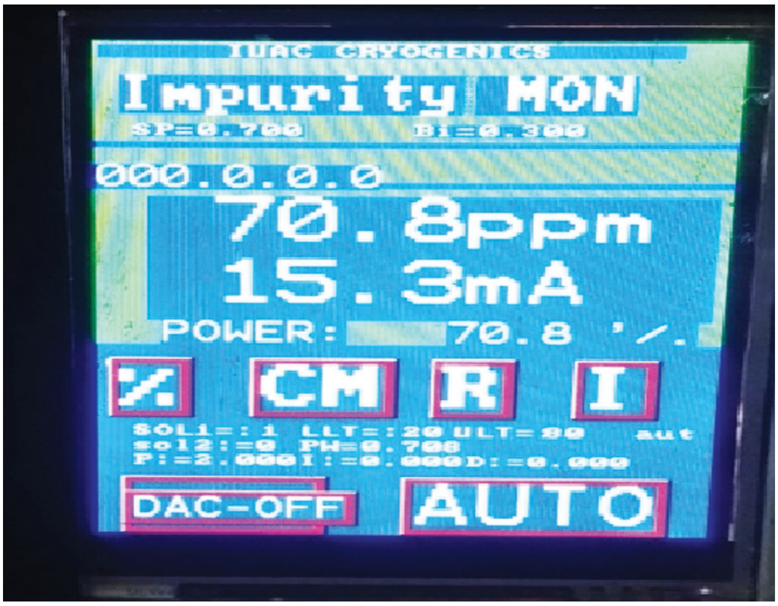

Fig 3.1.9: Impurity monitor device

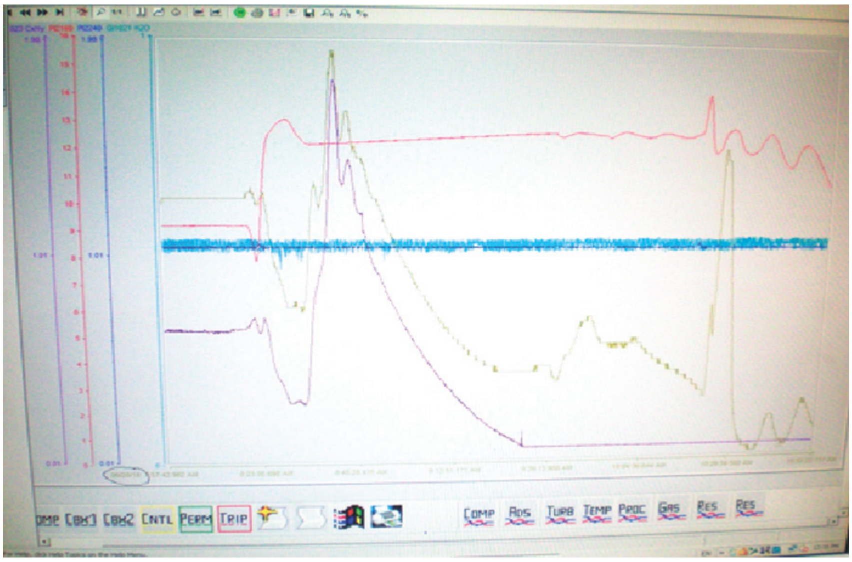

Fig 3.1.10: Historical trend

High Voltage device server (V/I monitor) for NAND
Joby Antony and Rajesh Nirdoshi

A device-server has been built for on-line monitoring & logging of NAND detector Voltage & Current (2kv, 5mA max) when connected in series with biased experimental detector. For data logging over Ethernet, this meter will be in series with load.

Other projects underway for HP Lab
Joby Antony, Birender Singh, Rajan Joshi

- A neutron monitor- read back system for PELLETRON is under way for a large number of channels mounted all across the Pelletron tower.
- A 48 CH PLC BASED RADIATION INTERLOCK SYSTEM for PELLETRON is also underway

IoT related devices built and tested

Sensors connected to IBM Bluemix cloud are explored to stream data to future to IBM Bluemix platform to analyse and visualize some cryogenic data. The device and the analytics are shown in fig. 3.1 11 & 3.1.12.

Fig 3.1.11: An IoT sensor connector de vice

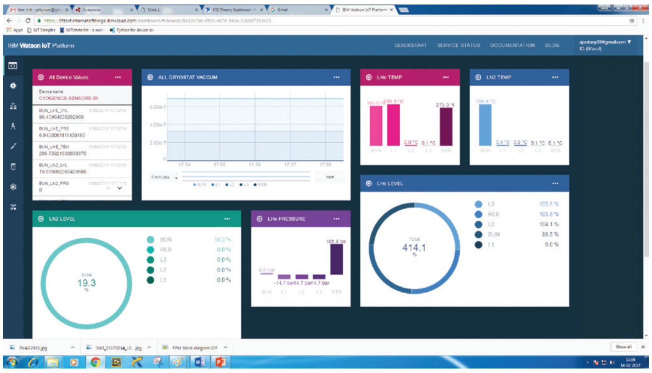

Fig 3.1.12: IoT Analytics using IBM Bluemix

A small 24 channel AI substitute on Ethernet backbone

A compact 24 channel Analog input device-server with 0-10 Volt DC inputs has been tested out to replace crate based technology like VME by a device running standard http sensor-server.(fig 3.1 13 & 3.1.14)

Fig 3.1.13: A 24 channel AI server

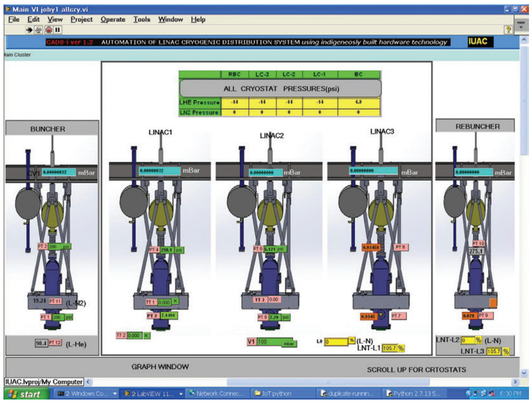

Fig 3.1.14: GUI under test

A Real time system for MRI Electronics using FPGA DSP
Joby Antony, Soumen Kar, T.S. Datta

The fast electronics for the upcoming MRI project is under preliminary design evaluation stage.
The main components of this project will be

1. Multi channel fast digitizer quench detection of MRI coils, simultaneous T,P,V parameters
2. The Fast system for Quench detector will measure, control and record .Real Time Stamping at 1mS

   Artix-7 FPGA based system with embedded Real time Linux real time-ARM target under cRio platform has been selected as the Hardware for all MRI development.
3. Labview® User interfaces.

Proposed system Hardware architecture and some initial test results are given in fig. 3.1.15 & 3.1.16 respectively. The Final system is under development.

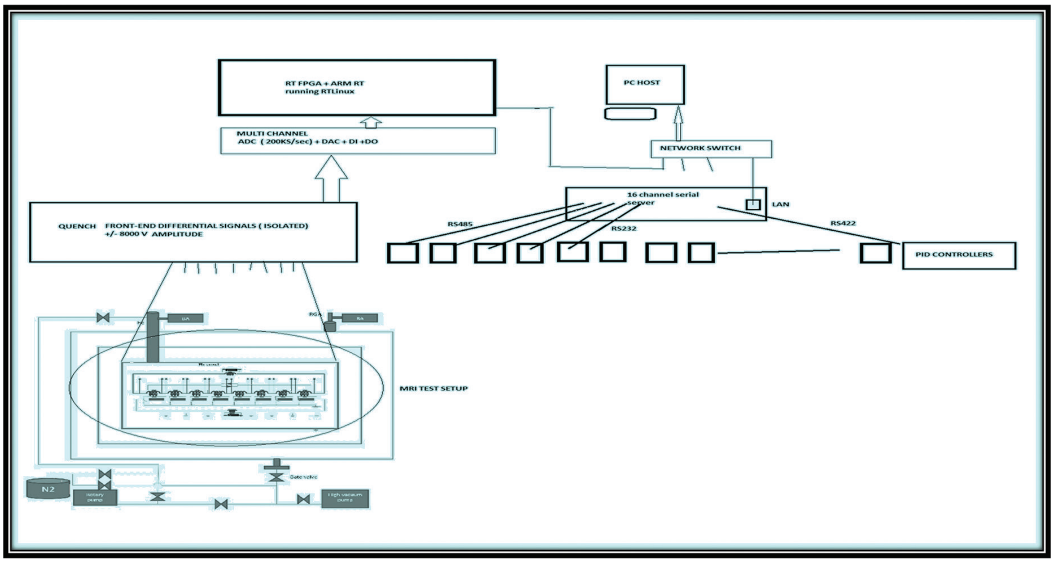

Fig 3.1.15: Proposed system Hardware architecture

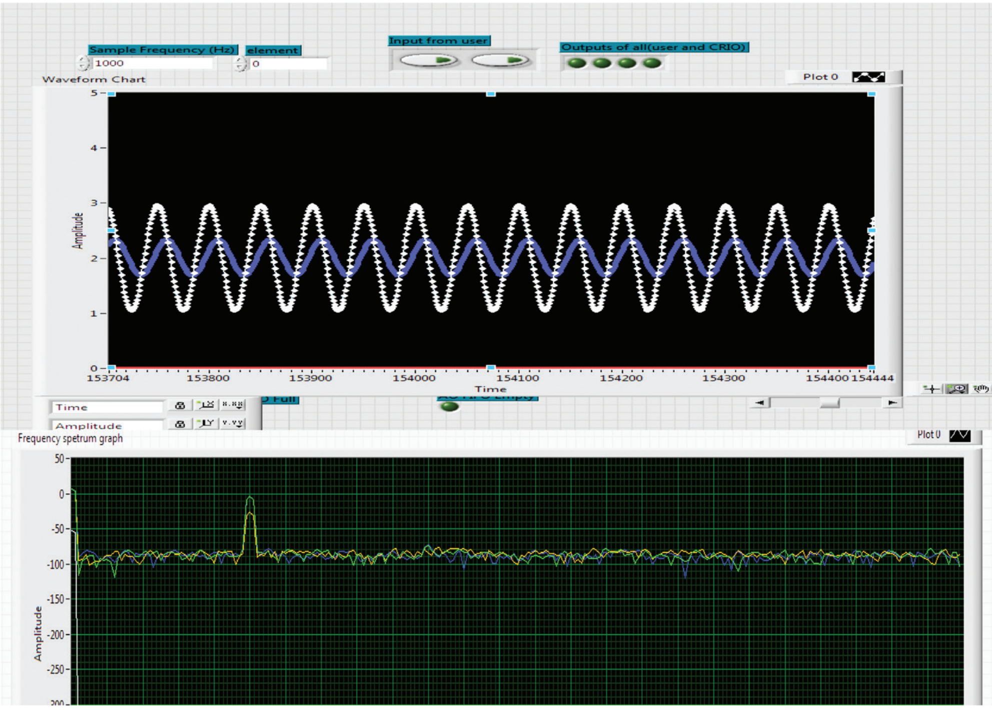

Fig 3.1.16: A Quantized fast signals in time and frequency domain in Lab

The other activities of the lab
Joby Antony and Rajesh Nirdoshi

Following units are under tests and development for future use

1) A PORTABLE DATA ACQUISITION UNIT – Ethernet logger for future use is started out and development is underway.

   An Industrial 8ch AI/8 ch 4-20mA current loop generator/8 ch 24 V DI/8 ch DO is being tried out using NI Compact FP. Hardware:
   cFP Compact Field Point - PAC Hardware has

   - Ethernet interface for PC-based distributed I/O
   - 1 RS485 and 3 RS232 serial ports for connection to peripherals

2) An Ethernet enabled Stepping Motor Controller

3.1.2.3 Applied Superconductivity & MRI

Development of a whole body 1.5T Superconducting MRI magnet system

Soumen Kar, Sankar Ram Theketthil, Navneet Suman, Vijay Soni, Mukesh Kumar, Rajesh Kumar, Joby Antony, R.G. Sharma & T.S. Datta

Ministry of Electronics and Information Technology (MeitY), Govt. of India has initiated a project to develop a 1.5T superconducting MRI scanner in India. It is multi-institutional project. SAMEER, Mumbai is the nodal agency of the project. Inter-University Accelerator Centre (IUAC), New Delhi is one of the partner institutes for the project on indigenous development of the 1.5T superconducting MRI scanner. IUAC-MRI team is primarily responsible for the development of 1.5T superconducting magnet and zero-boil off (ZBO) cryostat for the MRI scanner. Superconducting MRI system needs development of many complex technologies in the field of high-homogeneity superconducting magnet and zero-boil off cryogenic system. The technology of MRI is proprietary in nature because of its high commercial application.

The proposed MRI magnet will have multi-coil configuration: six primary coils to generate the central field of 1.5T at the iso-centre and two shield coils to generate the 5G safety line. The homogeneity of the magnet is ± 5ppm in 45 cm diametrical spherical diameter. Figure 3.1.17 shows the multi-coil magnet configuration and its axial field profile.

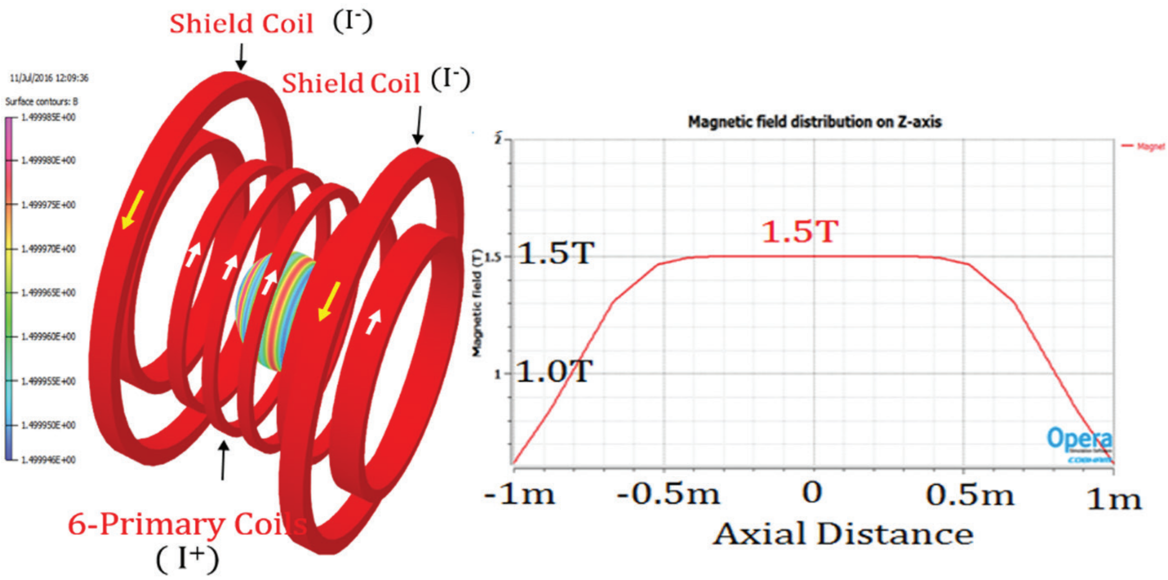

Figure 3.1.17 Multi-coil configuration of 1.5T MRI magnet and its axial field profile.

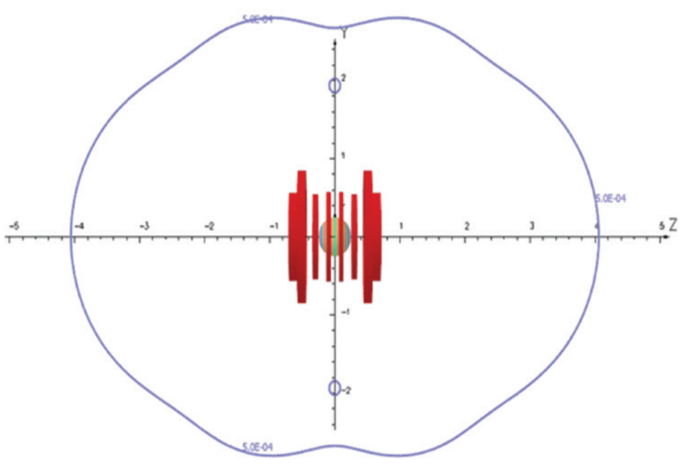

Figure 3.1.18 Iso-homogeneous lines of 2, 4, 6, 8 and 10 ppm homogeneity ; inner most blue line represents 2 ppm and outermost pink line represents 10 ppm [orange circle represents 45 cm DSV],

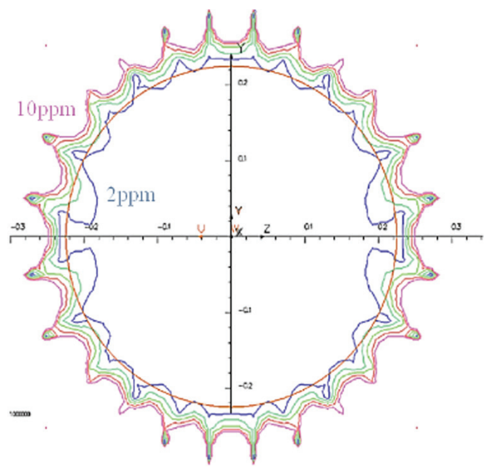

Figure 3.1.19 5G stray field region of the magnet at 1.5T central field. The corresponding peak-to-peak homogeneity is 9ppm.

Figure 3.1.18 shows the homogeneity profile of the 1.5T MRI magnet at 45cm DSV. It shows the iso-homogeneous lines of 2, 4, 6, 8 and 10 ppm homogeneity. The rms value of homogeneity is less than 1 ppm at 45 cm DSV. Figure 3.1.19 shows the 5G stray field region of the magnet. For any MRI scanner, one of the most critical requirements is the 5 G stray field beyond a certain permissible elliptical region for safety. Figure 3.1.20(b) shows the radial and axial spread of 5G safety footprint for the proposed 1.5T MRI magnet. The 5G safety footprint is achieved on the elliptical zone of 4 m (axially; Z_{5G}) and 2.6m (radially; R_{5G}). Hence, both axial and radial safety footprints are well within the medical guidelines for the MRI scanner.

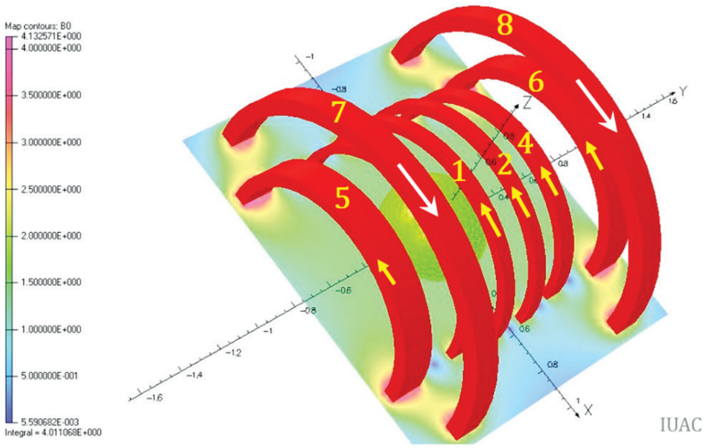

Figure 3.1.20 The field concentration on different coils of the 1.5T MRI magnet.

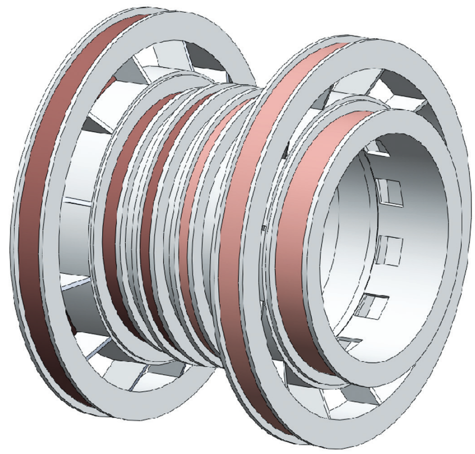

Figure 3.1.21 The field concentration on different coils of the 1.5T MRI magnet.

Figure 3.1.20 shows the field concentration on different coils of the 1.5T MRI magnet. The coil 5 (or 6) and coil 7 (or 8) experiences highest peak field which is approximately 4.2 T. The peak field would eventually determine the operating margin of the magnet. The proposed configuration of magnet would provide the warm bore the cryostat of ~ 0.9 m which will make the patient bore of 0.65 m after installation of gradient coil in the warm bore. The stored energy of the magnet is ~ 4.5MJ.

Bobbin is one of the critical components of the MRI magnet. Different configurations of the bobbin structure have been worked out. Bobbin mechanics greatly influence the performance of the magnet. Figure 3.1.21 shows one the bobbin configuration of the 1.5T MRI magnet. The bobbin will be made up of Aluminium alloy (AA 5083 H32). The stress due to the winding, thermal cool-down and Lorentz forces would finally determine the stress profile of the magnet and corresponding deformation during operation. The detailed FEA simulation is under progress to understand the bobbin-coil mechanics during operation of the magnet.

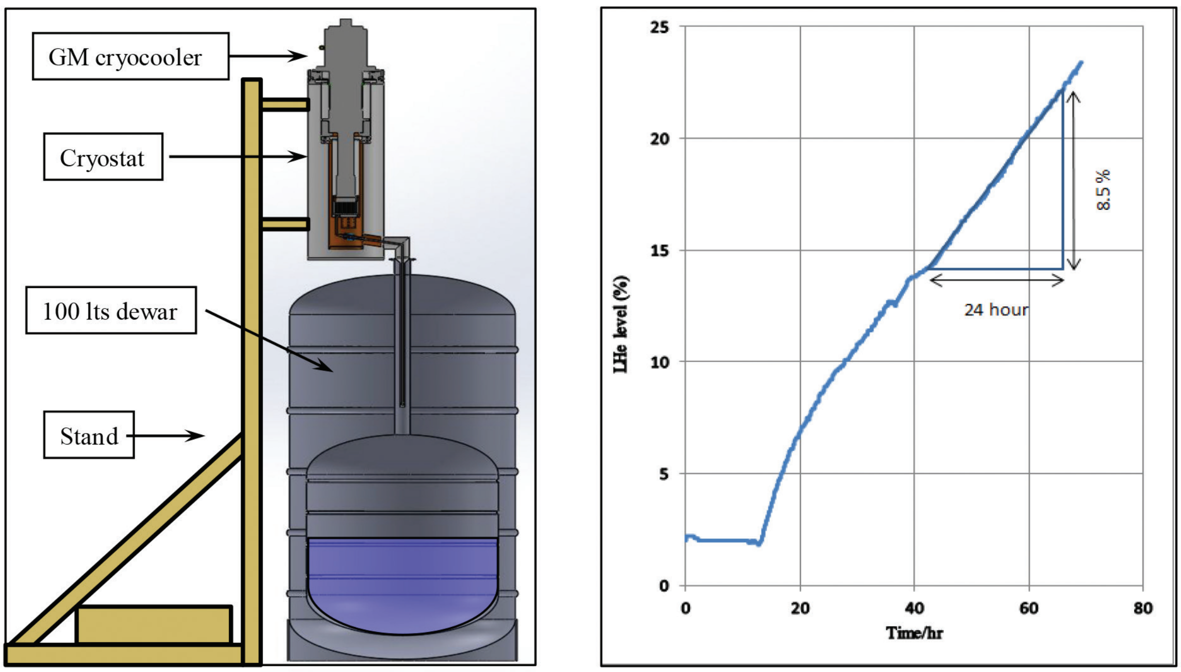

Figure 3.1.22 GM Cryocooler liquefier and its liquefaction rate

3.1.3 Power Supplies Laboratory

S.K.Suman, Mukesh Kumar and Rajesh Kumar

The primary responsibility of the Power Supplies Laboratory (PSL) is to support the operation and maintenance of accelerator beam transport magnet power supplies. The laboratory personnel are 24 hour on-call team, investigate beam trips caused by the power supplies and strive to minimize the number of trips and repair time. The laboratory designs different types of power supplies for magnets and other applications and manages the in-house production of these. The laboratory is also involved in design and fabrication of Low Level RF (LLRF) based RF cavities field control instrumentation for the upcoming High Current Injector (HCI) facility. (section 2.1.8). The activities related to development and maintenance are summarized below.

3.1.3.1 Fabrication of Power Supplies for HCI Beam Transport Magnets

The beam transport system of HCI will have approximately 30 steerer and 10 low power quadrupole magnets. To have control over maintenance and spare part availability, power supplies developed in-house will be used for these magnets. The in-house production of 70 numbers of linear bipolar power supplies (±5A/50V) for steerer and 10 numbers of unipolar power supplies (20A/20V) for low power quadrupole is going on. So far 30 power supplies have been assembled, out of which 22 power supplies have been put into operation in HCI and other accelerator facilities. This year, assembly of 15 more power supplies has been completed; the assembled power supplies are shown in figure 3.1.23.

3.1.3.2 Installation of magnet power supplies in HCI-LEBT section

The installation of HCI beam transport magnet and power supplies is being done and 15 numbers of homemade power supplies (including eight power supplies of this year) have been deployed with quadrupole and steering magnets in the HCI-LEBT section. These power supplies are in full operation throughout the year without any significant failure or breakdown. The power supplies are installed in 19" racks just below the magnets to keep the high current output cable length small as shown in figure 3.1.24. For every 10 power supplies, one additional power supply has been installed to keep redundancy.

Figure 3.1.23: The assembled power supplies

Figure 3.1.24: The installed power supplies.

3.1.3.3 Development of MOSFET based ±25A True Bipolar Power supply

The development is aimed to introduce a simple technique to eliminate zero crossover distortion in the presently used bipolar current regulated power supplies. The present design of such power supplies uses BJTs in push-pull configuration to have bipolar output current. In order to eliminate the crossover distortion associated with the push-pull output stages, additional feedback loops and accurately matched shunts are used to setup a quiescent current in the push-pull stage. This technique represents a major limitation, as it depends on the current gain of the BJTs, which decreases drastically at high output current. This technique is complex and needs additional control loops, specially matched shunts and high quiescent currents, which results in high power dissipation even at zero output current.

In the new technique, in place of BJTs, Mosfets are used and the quiescent currents are set by simply providing an offset voltage to gates. As Mosfets have high input impedance and constant current gain no additional feedback loops are required to control the quiescent current. The new technique is simple to implement and equally effective in low as well as high current bipolar amplifiers. To validate the performance of the new technique, a 25A bipolar power supply is assembled as shown in figure 3.1.25. The power supply has been operated at 100Hz, showing no trace of zero crossover distortion at full output current.

Figure 3.1.25: 25A Bipolar Supply

Figure 3.1.26: 500A Power Supply

3.1.3.4 Development of 500A/10V Power Supply for MRI Magnet Program

Superconducting (SC) persistent joint is one of the crucial technologies to be developed for the MRI magnet. The temporal stability of the MRI magnet is solely dependent on the SC joint between NbTi filaments. The joints need to be characterized at 4.2K up to 500A DC current. Special type of power supplies are needed for characterizing the SC joint because of their extremely low resistance value (~10-11Ω). In the year 1999, many such power supplies of 100A /10V rating were developed at IUAC primarily for the SC magnets of the LINAC and other offline setups. Instead of importing a single unit of 500A rating which would have been very costly, it was decided to use the in-house developed units in parallel to get the required current for characterization of the SC joints. Five such units have been integrated to make a modular 500A power supply. Master-slave control scheme has been adopted where the master unit performs the control and forces the remaining slave units to follow the reference current of the master. To enable the parallel operation of these power supplies, a tracking amplifier which generates a corresponding tracking signal of 0-5V for 0-100A output current have been incorporated in each module. The gain of each power supply has been accurately tuned to ensure equal current sharing. The total output current of the integrated module is equal to the set current at the master multiplied by the number of slave units. One additional slave unit is installed to have a N+1 redundant system, where N units are needed to power the load, but a "+1" supply is added for redundancy. The assembled 500A/10V DC Power Supply is shown in figure 3.1.26.

3.1.3.5 Design of a NIM based 3kV/3mA Power Supply

This is an effort to initiate a programme to develop HV power supplies for nuclear radiation detectors. The Power Supplies laboratory has developed such power supplies in past and presently provides repair service for these power supplies. It is becoming difficult and sometime impossible to repair these power supplies because of the old designs, obsolete spares and no circuit details. As large number and different type of detector bias HV power supplies are used at IUAC, so there is a scope for indigenous development of such power supplies to have complete control on maintenance. Initially a NIM based single width 3kV/3mA power supply has been designed, as a substitute to the photomultiplier tube bias power supplies. The new design is based on a hybrid topology of linear and switch-mode power conversion techniques delivering low noise with higher efficiency. The design of the new power supply is complete and the ferrite based inductive components such as HV voltage transformers and inductors have been fabricated. The PCB design and component procurement for the first prototype is in progress.

3.1.3.6 Development of fault current generator for AC characterization of HTS at 77K

The primary objective is to develop fault current generator for the characterization (cryogenic and electrical) of the 2nd generation HTS tapes at 77K for fault current limiting applications. A laboratory scale fault current generator, as shown in figure 3.1.27 (a) has been designed and constructed to study the effect of fault initiation angle and source impedance at the peak fault current, current limiting performance of HTS tapes, quenching and corresponding dynamic resistance development on HTS tapes, recovery under no-load condition, recovery under load and repetitive faults.

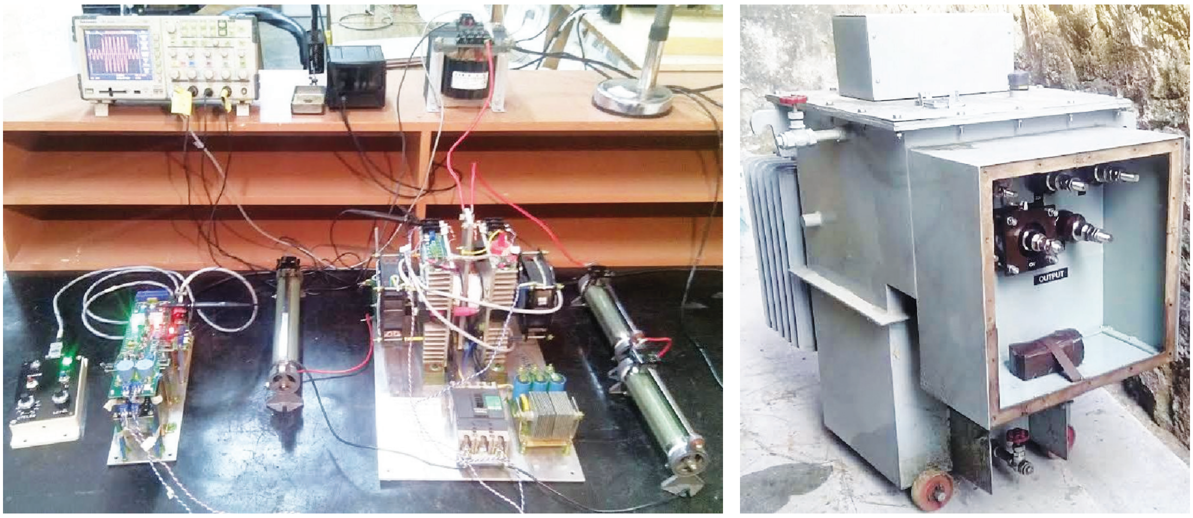

Figure 3.1.27 (a) Laboratory scale fault current generator and (b) step-down transformer

The fault generator provides the functionality to set the fault incident polarity, angle and the duration of the fault. The AC voltage source is a 60V step-down transformer (figure 3.1.27 (b), which can deliver 300A continuous current and a maximum 2kA short circuit current though HTS. The nominal current through the HTS tape is adjusted using a variable load resistor. The back to back connected power thyristor assembly is connected in parallel to the load resistor bank. When these thyristors are turned ON, there will a short circuit across the voltage source, resulting in a large fault current through the HTS tapes. Hence, the HTS tape will quench and become resistive, reducing the fault currents.

3.1.3.7 Accelerator Magnet power supplies operation status report

During this year the overall uptime of the beam transport magnet power supplies was recorded more than 99% and all the power supplies met the required performance in terms of stability. The power supplies failure logs were maintained over the period to summarise the required action to be taken during scheduled preventive maintenance. There were in total 17 breakdowns when the power supply unit itself failed or it was down due to the problem in the associated system such as water, electricity and remote control. These breakdowns amounted to 11 hrs of beam time loss throughout the year. As per the power supply failure log, there were 9 failures in the power supply units itself, 2 in beam line selector switchgear systems, one in remote control card and 4 in remote control system. Out of the 9 power supply failure, 2 were component level failures and the rest of the seven failures were arbitrary tripping of the power supplies due to corrosion problems in the fuse holders of the power supply transistor banks. The beam line selection system switchgears which connect a set of power supplies to the magnets of the selected beam line became increasingly troublesome because of corrosion in the switchgear contacts and we were forced to shut it down. During rest of the time the magnets of the selected beam line were connected manually and directly to the corresponding power supplies.

3.1.3.8 Preventive Maintenance of Magnets and the Magnet power supplies

Preventive maintenance was scheduled during February and March 2017. The tasks for the scheduled maintenance were finalised on the basis of the power supply failure log book and some were predetermined routine practices followed for the power supply maintenance. The failure data log is proving to be very useful in analyzing the current and future behaviour of the power supplies. Primarily, there were two targets during the scheduled maintenance period; the first was to take steps to control corrosion of the copper and silver plated surfaces in the power supplies and the second was the routine preventive maintenance of all the power supplies.

The cause of corrosion was studied in detail and many steps have been to taken to control. Early this year, symptoms of corrosion were observed in the power supplies. Small quantities of these corrosion products have created reliability issues in power supplies due to the formation of insulating corrosion layers. Silver coated fuse holders, heat sinks of the transistor banks, high current copper bus bars and magnet coil joints are the most affected parts in magnet power supply system. To analyse, why the power supplies are most affected, literature was surveyed and found that the temperature played a significant role in the corrosion rate and corrosion rate is maximum at 40ºC. Power supplies being power handling devices, most of time run at elevated temperatures and that may be the reason that these are most affected.

In order to minimize the corrosion effects, efforts are made to control the dust levels, which act as carriers to these chemical pollutants. Beam lines and experimental facility areas were rearranged, floor areas cleared to remove the accumulated dust and enable the periodic cleaning of these areas. Also it was decided to change the transistor bank silver coated fuse holders periodically and use gold plated contacts wherever possible. During this scheduled maintenance period the fuse holders of 35 power supplies have been replaced. The fuse holders of rest of the power supplies will be changed in the next scheduled maintenance period.

Preventive Maintenance

Preventive maintenance of the power supplies has been carried out in order to minimise down time and to ensure stable and reproducible operation. Predetermined proven maintenance procedures are followed for each power supply. A format has been made containing all the important electrical parameters and test point information of the power supply. During preventive maintenance it has been made mandatory to furnish all the test details of each power supply in this format for future reference. The power supplies and magnets were checked for loose connections, hot spots, corrosion and water leak. Compressed air and dirt cleaning solvents are used to keep all the power supplies and magnets clean. Safety interlock failures were deliberately generated and tested to ensure their proper functioning during abnormal conditions. Remote control data read-write and on-off commands were checked thoroughly for any malfunction. Full power test was conducted after finishing all servicing procedures and the test details were furnished in the test format. Necessary spare parts were listed out.

3.1.4 Detector Laboratory

Mohit Kumar and Akhil Jhingan

Detector Laboratory at IUAC provides experimental support to various users in setting up charged particle detectors and readout electronics. New detectors and electronics have been designed and developed, and are used in various user experiments in HIRA, HYRA, GPSC and NAND. Detector lab provided training on experimental activities for Scientist Trainees, JRF, M.Tech, B.Sc and M.Sc students.

3.1.4.1 Double arm TOF spectrometer

A. Jhingan, N. Saneesh, M. Kumar, S. Santra (BARC), R. Ahuja, P. Sugathan

A double arm TOF spectrometer was installed in GPSC to perform fission mass distribution experiments. The spectrometer has two TOF arms based on multiwire proportional counters (MWPCs), each of which have two MWPCs forming a start-stop detector system. The start detector has an active area of 2 x 2 cm^2. They have 3 electrode geometry with cathode made out of a mylar foil (2 µm thick) sandwiched between two grounded anodes. The anodes are wire frames made out of gold plated tungsten wires of diameter 10 µm with inter-wire separation 0.63 mm. The entrance and exit foils are 0.5 µm mylar. This design provided a very fast timing, with rise times ~ 2 ns, as compared to our previous design of multi-step geometry having four wire frames (rise times ~ 4 ns). On the other hand, present design introduces more straggling of fission fragments. An average loss of 25 MeV for fission fragments has been observed in the 3 foils of start MWPC. Stop detectors are position sensitive MWPCs [1] with area 16 x 11 cm^2. The TOF spectrometer was used to study the fission mass distribution for the system $^{6,7}Li + ^{238}U$. The start detectors were placed at a distance of 10 cm from the target. TOF distance between start and stop detector was 25 cm. The set up also had 16 CsI detectors for detecting light charged particle spectra in coincidence with fission fragments.

3.1.4.2 CsI detectors

A. Jhingan, K. Kapoor (PU), N. Saneesh, M. Kumar, A. Kumar (PU), P. Sugathan

New set of charge sensitive preamplifiers (CSPA) were fabricated for integrating with CsI scintillators read by photo-diodes. The earlier design [2] had a common mother board with vertical CSPA daughter cards for signal processing. This design had real estate issues in case of close pack array with higher probability of noise pick-up and cross-talks. The new design eliminated the daughter card, and the four CSPA channels were assembled in 2 x 2 format in an area of 4 cm x 4 cm. For miniaturization, SMD components of package 0402 were used to assemble these CSPA. The photo-diodes are mounted on the other side CSPA board. A four layer board was designed for the same. The assembled units were used to perform fission gated charged particle multiplicity measurements for the systems $^{16}O + ^{196}Pt$ and $^{6,7}Li + ^{238}U$. The signals were extracted using miniature coaxial cables. In our earlier measurements, LEMO feedthroughs of the GPSC chamber were used for signal transmission. In the present case a PCB based flange with 17 pair FRC connectors was used. An eight channel board has also been designed in 3 + 2 + 3 format with a central hole for beam passage. The board will be assembled and tested in coming months. All the boards have a common bias and test input.

3.1.4.3 Instrumentation

Fast timing preamplifiers were fabricated and provided to nuclear physics group, BARC for signal processing with position sensitive MWPCs. A total of ten preamp circuits along with common voltage distribution for the preamps were provided. A pair of position sensitive MWPCs with three electrode geometry have also been provided for performing fission mass distribution experiments with TIFR-BARC Pelletron-Linac accelerator system.

3.1.4.4 New detector systems

New detector systems are being planned for performing measurements such as ER gated neutron multiplicity and development of 2v-2E system for fission mass distribution experiments. In both cases new MWPCs are being designed and developed. For 2v-2E measurements, it is planned to integrate a large area silicon strip detector (SSD) with the MWPC. This work is being carried out in collaboration with the GANIL group. A SSD of area 10 x 10 cm^2 has been provided by the GANIL group. MWPC will provide timing (velocity) and SSD will provide the energy. To reduce the neutron scattering, new aluminium bodies have been fabricated with counter sunks.

3.1.4.5 Activities in NUSTAR

Designing of detector systems required for low energy branch of NUSTAR has been initiated. Test measurements were performed to study the timing characteristics of beam tracking detectors such as position sensitive micro-channel plate (MCP) detectors. For identification of secondary reaction products, a thin SSD of thickness 20 um was also tested for its timing characteristics. The timing signals were processed using the 16 channel fast timing amplifier developed at IUAC. The measurements were performed using ^{124}Xe beam at 200 MeV/A from UNILAC-SIS18 synchrotron accelerator system of GSI, Darmstadt. The beam was slowed down to 10 MeV/A with an intensity of 10^5 pps. The detectors could handle these high count rates. An ionization chamber is being designed for identification of cocktail species from fragment separator. Further developments will be carried out on approval of technical design report and availability of funds from Indian FAIR coordination committee.

REFERENCE

[1] A Jhingan et al., Proc. DAE-BRNS Symp. Nucl. Phys. 60 (2015) 936

[2] NIM A 786 (2015) 51

3.1.5 Target Development Laboratory

Abhilash S. R. and D. Kabiraj

Nuclear target development

Target development for IUAC users is the primary responsibility target lab. Most of the instruments in target lab were well –utilized by users in 2016. Man-machine utilization in target development laboratory is shown in Fig.3.1.28.

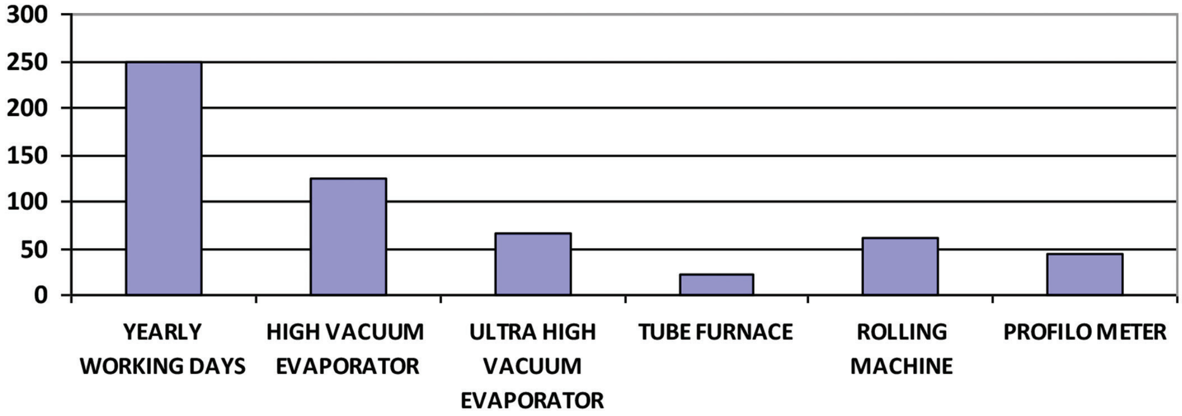

Fig. 3.1.28- Utilization of time

Table 1 - Utilizatation of facilities

Facility	No of attempts
High Vacuum Evaporator	124
Ultra- High Vacuum Evaporator	33
Tubular furnace	23
Rolling Machine	61
Profilo Meter	43

It indicates that one or more than one facility of target lab had been used every day in the last year. More than 200 attempts were performed for target fabrication in different systems. In addition to IUAC Pelletron users from universities, target lab provides target-related services to premier institutions viz; IITs, ISRO, VECC, TIFR and BARC. Target developments in IUAC were also reported in national and inter-national conferences [1-3].

Recent updates in Isotopic Target development

Approximately 80% of the time is devoted for the fabrication of isotopic targets (Table2). Few nuclear targets developed in the last year were the first-time-development. Most of the targets are fabricated by physical vapor deposition method (thermal evaporation and e-beam method).

Table.2: List of isotope target developed

Sl.No	Description of target	Thickness
1	^{52}Cr	1mg/cm^2
2	^{52}Cr	0.65mg/cm^2
3	^{187}Re	200µg/cm^2
4	^{193}Ir	200 µg/cm^2
5	^{160}Gd	150 µg/cm^2
6	^{160}Gd	300 µg/cm^2
7	^{48}Ti	800 µg/cm^2
8	^{198}Pt	6mg/cm^2
9	^{122}Sn	11mg/cm^2
10	^{100}Mo	1.5mg/cm^2
11	^{121}Sb	600 µg/cm^2
12	^{208}Pb	440 µg/cm^2
13	^{186}W	500 µg/cm^2
14	^{160}Gd	100 µg/cm^2
15	$^{208,206}Pb$	200µg/cm^2

In the target development of isotopes, preparation and preservation of oxidizing elements were always a challenging job. Minimizing the exposure of target materials to atmosphere plays the significant role. Since many of them are of rarely available isotopically enriched materials, minimizing the material consumption and its preservation for longer duration not only saves the money but also the valuable time of researchers. Carbon and gold sandwiching of targets found to be an effective method to prevent targets from oxidation. After preparing the suitable backing of gold or carbon, deposition of the target material and capping material are done sequentially in a single set-up without disturbing the vacuum. Since both sides of the target surfaces are covered by carbon or gold, the targets remain protected from oxidation. The optimized thickness of carbon backing and capping were 10-20µg/cm^2 and 5µg/cm^2 respectively. The thickness of gold backing and capping were ~10mg/cm^2 and 100µg/cm^2 respectively. This procedure was capable to produce 15-24 targets in one attempt. We had recently fabricated Pb and Ba targets sandwiched between carbon layers and Zr and Pr, Ca targets in between Au layers.

Contamination from the parting agent was a major issue faced in the last year in the isotopic target fabrication. Target lab had done a systematic study about this issue. NaCl, $BaCl_2$, KCl, CsI and teepol are the main parting agents in regular use. Teepol was used when the substrate temperature is maintained well below 100ºC. NaCl and $BaCl_2$ can withstand higher temperature. In a recent ^{208}Pb preparation, both $BaCl_2$ and KCl were used as parting agent of carbon backing. In the RBS characterization, contamination from the parting agent was traced in the targets. The contamination was more in annealed films. In the comparison, contamination of $BaCl_2$ was more than that of KCl (Fig. 3.1.29). In many films which used KCl as parting agent was relatively free from contaminations. The conclusion of the study is that if contamination due to $BaCl_2$ will adversely affect the experiment, KCl can be used as an alternate option.

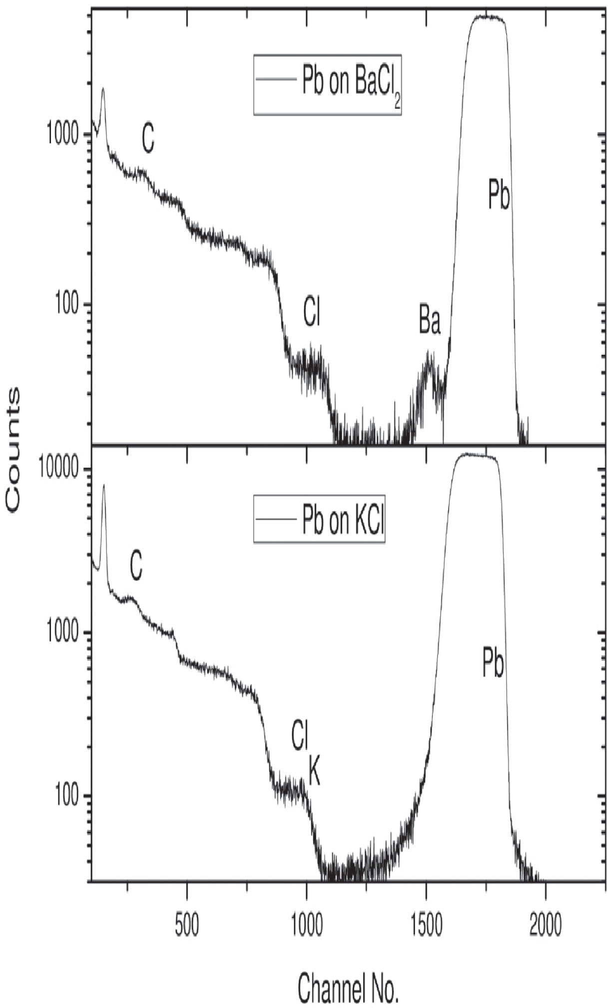

Fig.3.1.29: RBS Spectra of Pb targets

Target fabrication at elevated substrate temperature especially optimizing the substrate temperature for the different elements was another important development in the last year. Many elements, viz; Cr, Er, Pt and Co do not stick properly to the substrate when it is at room temperature. Crack in the film while floating is also a major issue. Substrate temperature is one of the important parameter which influences the properties of thin films during deposition. Elevated substrate temperature can minimize cracks in the films. High temperature of the substrate increases mobility of the vapor atoms and helps in obtaining the defect/stress free films. However, high temperature can be a reason for re-evaporation of condensed particles also. Therefore finding an optimum temperature is a main task. Many targets of Zr and Cr have been fabricated at high substrate temperature.

Target development with minimum material consumption is always primary effort since isotopes are highly expensive and target lab had already initiated steps to minimize the material consumption. Controlling the solid angle of evaporation plays significant role in increasing the efficiency of evaporation. Recently we have deposited 1.7mg/cm^2 of Sb using 5.3mg of Sb by indigenously developed graphite crucible. Simultaneous fabrication of targets of varying thickness is also an effective method to reduce the material consumption. This method can meet the requirement of more than one user in a single evaporation without additional amount of material. In the last year, target development lab was successful in the development of ^{174}Yb of ~763 µg/cm^2 and ~125 µg/cm^2 simultaneously by using only 49 mg of isotopic material. The same method was also employed in the production of 10 targets of ^{184,186}W of ~600µg/cm^2 and 150µg/cm^2.

We have also fabricated many isotopic targets by rolling technique. Though the rolling technique is limited to ductile material in the order of mg/cm^2, recently target lab is successful in the fabrication of ^{160}Gd of ~300µg/cm^2 by rolling technique.

Fabrication, Inspection and Loading of stripper foils

More than 200 imported carbon stripper foils and 300 IUAC foils of 4µg/cm^2 were loaded in the last year. Foils are imported in the form of carbon films coated on glass slides. Floating of the foils, etching of the foils in the acid solution to remove the copper backing, mounting of the foils on stainless steel frame and finally loading of the foils in the terminal of the Pelletron are the major responsibilities in this work.

Step height measurement by Stylus Profiler

This is the latest addition in the list of facilities in Target lab. The Dektak stylus surface profiler is an advanced thin and thick film step height measurement tool. In addition to profiling surface, it can measure roughness of the surface in the nanometer range (Fig.3.1.30). Many users have already availed this facility for the measurement of thin film thickness.

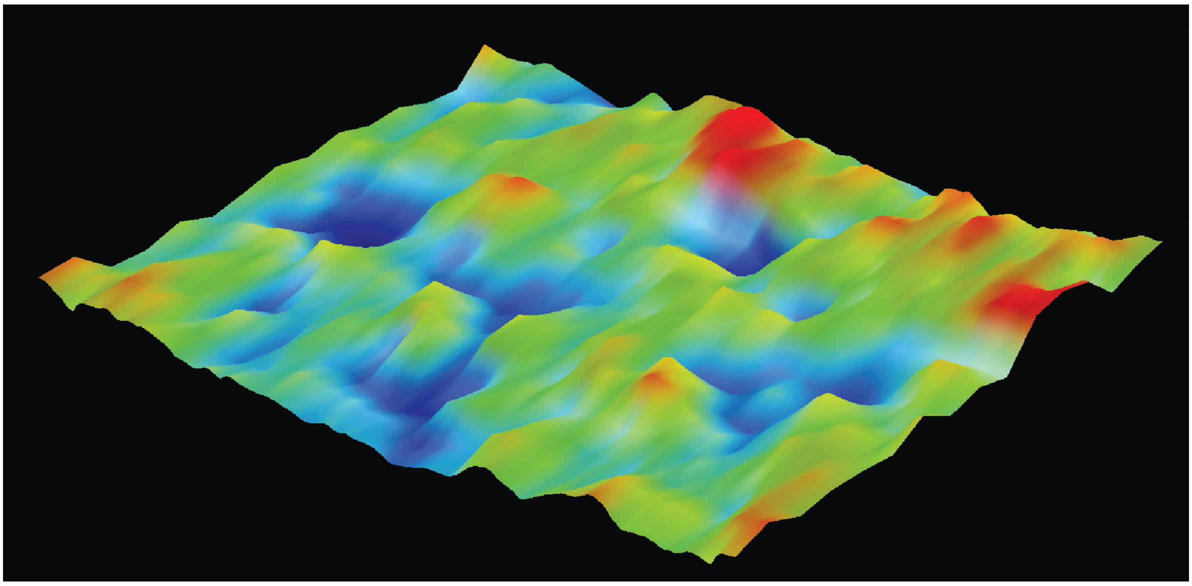

Fig.3.1.30: 3-D image of a thin film

Sample preparation facility for Transmission Electron Microscopy

A state-of-the-art TEM sample preparation facility has been established in IUAC. The set-up includes set of instruments to ensure smooth support to the IUAC user community. The main instruments are ultrasonic disc cutter, dimple grinder, disc grinder, hot Plate, precision ion polishing system and a diamond wire saw. Few of us got training from the supplier. We have already prepared many samples on trial basis. Both planer and cross-section TEM sample can be prepared.

REFERENCE

[1] Abhilash S R et.al; Proceedings of 28th World Conference of the International Nuclear Target Development Society, Nov 13-18, 2016 Cape Town, South Africa.

[2] Abhilash S.R et al;1062, Proceedings of the DAE-BRNS Symp. on Nucl. Phys. 61 (2016).

[3] Kavita Rajput et.al;526 Proceedings of the DAE-BRNS Symp. on Nucl. Phys. 61 (2016).

3.1.6 RF & Electronics laboratory

A. Sarkar, S. Venkataramanan, B.K. Sahu, K. Singh, A. Gupta, M. Jain, P. Singh, D.K. Munda, A.Sarma and B.P.Ajith Kumar

3.1.6.1 Development of Charge Sensitive Pre-amplifier for INGA type clover detector

The clover type HPGe detector of INGA (Indian national Gamma Array) at IUAC requires replacement pre-amplifier boards. In order to have import substitute of these pre-amplifiers, we have successfully developed two different types of charge sensitive pre-amplifier cards (type: 821 & 823) for these detectors, tested and mass produced as per requirement. We have initially characterized with test pulser and clover type HPGe detector at INGA of IUAC. With pre-amplifier type 823, typical resolution measured (48 hours test) with test pulser and radiation source Co-60 are 1.7keV and 2.7keV (1332 keV) respectively.

3.1.6.2 Multiplicity modules for NAND array

At present, signals from 100 neutron array detectors and corresponding front end electronics are being processed with homemade Pulse Shape Discriminator (PSD) modules. In order to improve the data collection efficiency, optional Multiplicity logic is being implemented with the NAND array. A generic "16 channel Multiplicity & "OR" logic module" and a "Master Multiplicity module" are assembled and tested with radiation source. The "16 channel Multiplicity & "OR" logic module" accepts CFD (F/NIM) signal from each PSD channel and its corresponding extended width (250ns) signals at -2mA/detector are generated. The analog sum of these extended width signals is available at 50 ohm node, located at Master Multiplicity module. The Master Multiplicity module is capable of accepting signals from 8 Nos. of "16 channel Multiplicity & "OR" logic module. In order to accommodate >100 detectors, seven (7x 16) such modules are fabricated and implemented. The OR logic is nothing but a logic OR of extended width signals available from each PSD channel. The different level of multiplicity threshold (up to 5) can be set in Master Multiplicity module in order to generate corresponding master logic signal (F/NIM).

3.1.6.3 Development of electronics for charge particle detector array (CPDA)

In the CPDA set-up, consisting of 72 CsI (size:10×10×10 mm^3) + Si-PIN Photo diode array, the signal coming from pre-amplifier is very weak and needs pre amplification before feeding it to a shaping amplifier. Also the pre-amplifier signal is single ended and needs to be converted to differential signal to drive over long distance through twisted pair cable to minimize noise pickup. In this intermediate stage, additional amplification (gain of +10) also takes place. The first prototype has been designed, developed and tested with 4 nos., CsI (Tl) detectors and in-house developed low power charge sensitive preamplifiers (25mW) using ^{137}Cs and ^{60}Co sources at IUAC. The detectors are biased at -30V. Ballistic deficit method is implemented by comparing the output of two shaping circuits having different shaping constants (long: 3us and short: 1us). We have measured the resolution of <6% for 1.3 MeV of ^{60}Co and <10% for 662 keV of ^{137}Cs. We plan to test the array inside a vacuum chamber with available detectors in near future.

A portable regulated, stable and low ripple output power supply has been designed and developed for powering electronics of charge particle detector array (CPDA) of INGA. This unit provides linear regulated +/-6V@2A and switch mode regulated power supply (-45V@20mA) to bias front end electronics and detectors respectively. Front end electronics includes pre-amplifiers and its driver module. It also generates a test pulse signal to test the pre-amplifier functionality. The detector bias and test pulse amplitude can be adjusted by the controls provided on front panel. All the dc outputs include fold back current limiting circuit to provide protection in short circuit and overload condition. It has been successfully tested with test set-up.

3.1.6.4 MIDAS Digital Data Acquisition System (DAQ)

MIDAS (Maximum Integrated Data Acquisition System) is a general purpose software package for event based data acquisition in Physics experiments. It is an open source (under GPL) modern data acquisition system developed at PSI (Paul Scherrer Institute), Switzerland and TRIUMF, Canada. It is based on modular networking and mainly consists of a collection of C, C^{++} code, handling the main functionality required for data communication between the different nodes, data control for run operations, data distribution for online data analysis and much more. The experiment complexity ranges from a simple test system with single front-end computer and node to experiments with several front-end computers and analysis nodes. For remote web based control and monitoring it has necessary built-in tools. Presently MIDAS is supported on Unix (Scientific Linux, Ubuntu, MacOS), windows and real time OS like VxWorks. It has been used worldwide in leading research laboratories and development continues with additional new features and tools in both traditional electronics (analog chain) and modern digital electronics (digitizers). Very recent developments involve multi-threading, Linux support etc. MIDAS can be used in a standalone and distributed environment where one or more front-ends (application software acquiring data from the actual hardware) and are connected to the back end (application software handling the collection of data from front end and managing the run sequence via network (i.e. Ethernet). Presently we have implemented the front end for 250 MSPS CAEN digitizer for the timing investigation using fast scintillator detectors. We are finding it very useful for our NAND array (100 neutron detector array) at IUAC with over 100 neutron detectors signals to acquire/process in digital domain.

3.1.6.5 Spark Protection Boards for IUAC Control System

A new 32 Channel Spark Protection Board (compatible with VME bus based control modules) has been designed and developed to protect VME control system from damage by high voltage electrical sparks. The protection circuit has two layers of protection. The first layer is a Zener diode based transient voltage suppressor that limits the input voltage by shunting the spark energy to ground potential. The second layer of protection is a passive filter that blocks the high frequency energy of the spark. There are four types of 32 Channel Spark Protection Boards developed for VME based control system.

- ADC Spark Protection Board.
- DAC Spark Protection Board
- Input Gate (IG) Spark Protection Board and
- Output Register (OR) Spark Protection Board.

3.1.6.6 Broad band amplifier & Ultra-fast discriminators unit for capacitive pick-off of Linac

In order to measure the energy of pulsed beam energetic particle obtained with Linac in a non-destructive manner using capacitive pick-off, time-of-flight (TOF) technique is utilized with Linac at IUAC. Such techniques require consistent time marking of arrival of pulsed beam from capacitive pick-off irrespective of intensity of the beam. Low level ultra fast discriminator (fig. 3.1.31) technique is very useful for this application. Each channel consists of a broadband amplifier (+20dB, >10Mhz-2GHz) and an ultra fast discriminators in cascade to generate the low level discriminated logic pulse (raw). The raw logic pulse can be generated from leading edge or trailing edge of the incoming pulse with edge selection. The low level discriminated pulse is further shaped to generate fast NIM logic pulses. State of the art 100KH ECL devices are used to develop this circuit. A dual channel, single width NIM module is developed with these functional blocks and used with the Linac control setup.

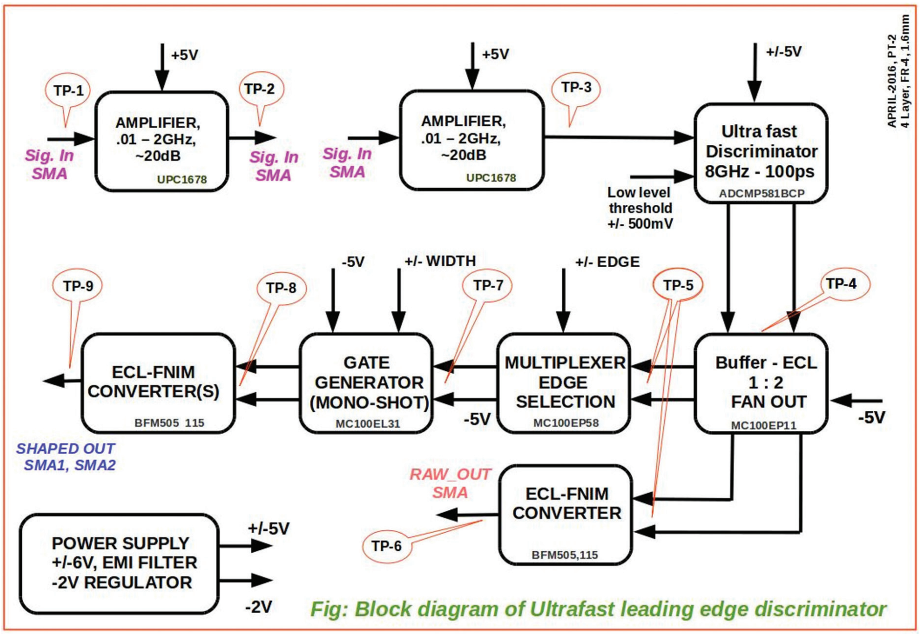

Fig 3.1.31: Block diagram of Ultra fast leading edge discriminator

3.1.6.7 Development of 2kW, 48.5MHz Solid state power amplifier

A 2kW broad band solid state power amplifier (fig. 3.1.32) has been developed with following specifications for spiral buncher of high current injector (HCI). The design based on the state of the art 6th generation LDMOS power devices have been adopted in order to have compactness, high power gain, reliability and efficiency. The amplifier is based on splitter combiner concept, wherein 2-way transmission line type Wilkinson power splitter and combiner (at 48.5MHz) are adopted. The control circuit incorporates over drive limit, auto level control (ALC). A high power three element low pass filter ensures suppressed harmonics below 60dBc. The entire amplifier is mounted on a water cooled aluminium heat sink, and packed in 2U height 19" cabinet. The amplifier has been characterised for various crucial parameters and burn-in tested for a week.

Specifications:

- Power output: ~2kW
- Power gain: >70dB with gain flatness: +/-1.5dB
- Bandwidth: 10MHz - 65MHz (peaking at 48.5MHz)
- Efficiency: Better than 60%

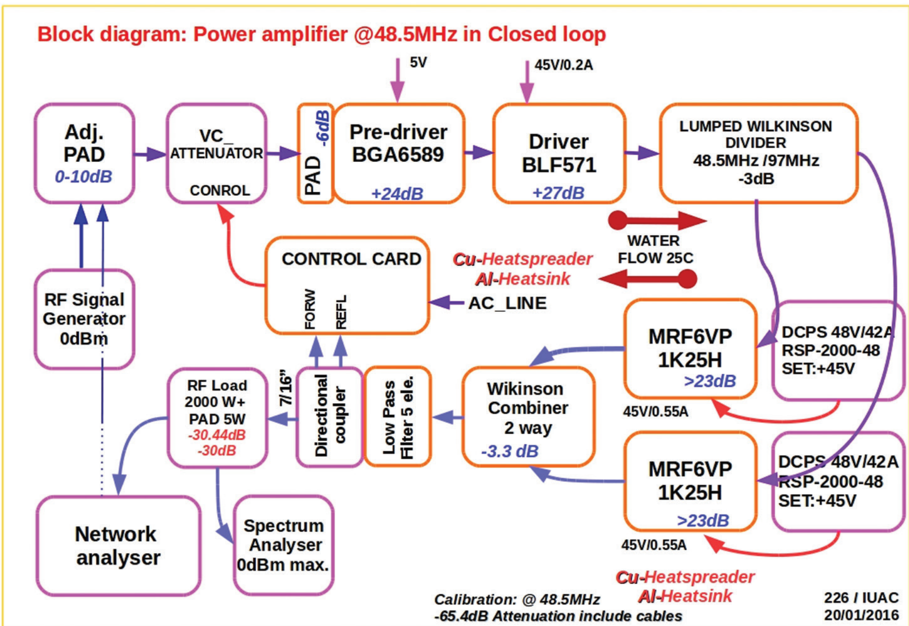

Fig 3.1.32: Block diagram of 2kW, 48.5MHz RF amplifier

3.1.6.8 Status of 400W, 97 MHz Solid State RF Power Amplifier for LINAC

Superconducting LINAC cavities are being powered using indigenously developed 400W @97MHz solid state RF power amplifiers. As the LINAC operation demands long time operation of RF amplifiers in continuous mode (CW), preventive and breakdown maintenance is carried out on routine basis. This year during testing and operational cycle of Linac, 9 nos. of RF amplifiers were found to be malfunctioning. All the faulty RF amplifiers were removed from their respective locations after disconnecting power and water lines. In addition to this, remaining amplifiers were removed and preventive maintenance was carried out.

All the non-working RF amplifiers were physically inspected, and it was found that all components of amplifiers were covered with thick layer of dust, some of the components such as voltage controlled attenuators, RF power core PCBs, trimmer capacitors were rusted due to moisture collected on the components. This is probably due to imperfection in ambient temperature control of air conditioning and cooling water. All damaged components were replaced, re-calibrated and subjected to standard test procedure. Preventive cleaning of remaining amplifiers was also carried out during this period.

3.1.6.9 Development of RF power read-back module

Typical power read-back available from the RF amplifiers is non-linear; the margin of error in the RF power read-back of each resonator during operation of superconducting linac is very high. In order to rectify this problem, another 10 channel RF power read-back module has been successfully developed for the superconducting cavities and installed inside Linear accelerator. The module receives the input from the sampled RF power from directional coupler of each amplifier. The module consists of RF attenuator, RF power detector and signal amplifier. The RF detector converts RF signal to proportional DC voltage linearly which is further scaled to appropriate range by the amplifier. Each channel has three inputs which read forward, reflected and pick-up power of the cavity. Modular concept is adopted for easy repair and maintenance. The RF detectors are mounted on a copper heat spreader to keep the temperature constant. Two SMPS having rating of 5V, +/-15Vdc are used for biasing detectors and operational amplifiers. The entire system is mounted inside 2U, 19” aluminum enclosure. The DC output obtained from each channel is calibrated and the same is specified in the control system database with scanning ADC for remote read-back and monitoring. The detail specification a block diagram is given below.

Specifications:

- Input Forward Power : 0 to + 30 dBm (@ 97MHz)
- Input Reflected Power : 0 to + 30 dBm (@ 97MHz)
- Input Pick-up power : -25 to +13 dBm (@97MHz)
- Output Forward, Reflected & Pick-up : 0 to 10Vdc (Linear)
- Input connectors : BNC Male.
- Output connectors : D-type Male.

3.1.7 Health Physics

Debashish Sen & Birendra Singh

The radiation safety aspect of the Accelerator Centre is taken care by the Health physics group, along with radiation safety related research and development. Routine maintenance of door interlock and radiation monitors is done regularly to keep a vigil on the overall radiation safety.

Many university faculties and research scholars are using the facilities (gamma irradiation chamber, TLD reader, electrochemical work station etc.) developed and maintained by this group. A few of the research scholars have completed their Ph.D. using the facilities and a few research scholars are continuing to do so.

Gamma irradiation chamber is open for different users from universities and Institutions. The chamber is working fine after being successfully relocated to a different place within the office premises in the presence of BRIT officials. AERB team had monitored the newly installed facility and had suggested some extra safety measures, which were immediately implemented. Permission for the design, construction and trial run of the **AMS** facility has been received. It was subjected to some particular safety measures which have already been implemented. The Site approval for the upcoming **FEL** (Free Electron Laser) & **HCI** (High Current Injector) facilities in IUAC has also been received. Regular status reports for the **Gamma irradiation chamber, Pelletron** and **RBS** facility are being sent to AERB. All dose records are maintained and are also available online.

Calibration of all the gamma monitors and survey meters installed/used in IUAC had been carried out in the previous year. In the current year, **two neutron monitors/survey meters were calibrated at BARC** under their strict monitoring. Also the door interlock system of Vault 1 underwent thorough repair.

3.1.7.1 AERB Approval for different upcoming radiation facilities of IUAC (regarding radiation safety aspects)

Debashish Sen

A. Accelerator Mass Spectroscopy (AMS) facility

The design & construction, along with trial run approval has been sanctioned. Shielding aspects has been taken care of and approved by AERB. Fig. 3.1.33 shows the beam hall layout of the facility.

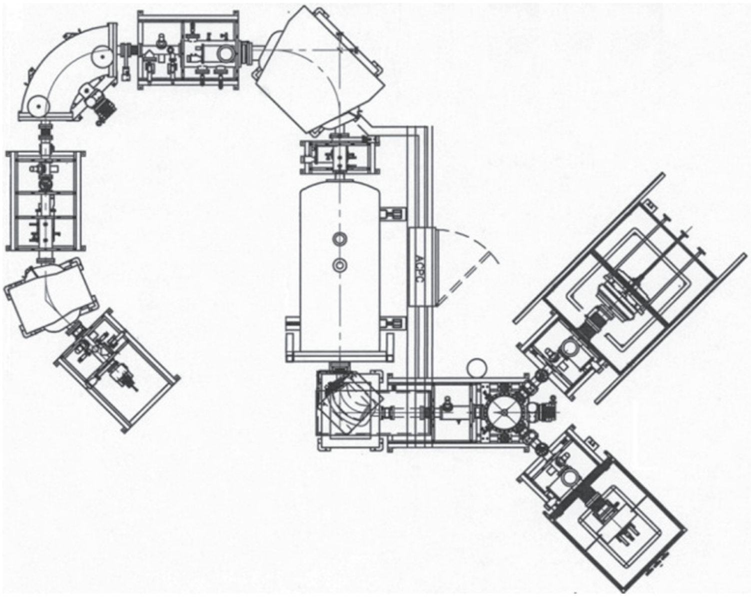

Fig. 3.1.33 IUAC AMS facility: beam hall layout

B. Free Electron Laser (FEL) Facility (Delhi Light Source (DLS))

The Site approval has been sanctioned for FEL facility whose tentative layout is shown in fig. 3.1.34. The design & construction approval application will be submitted soon. Shielding calculations are under way.

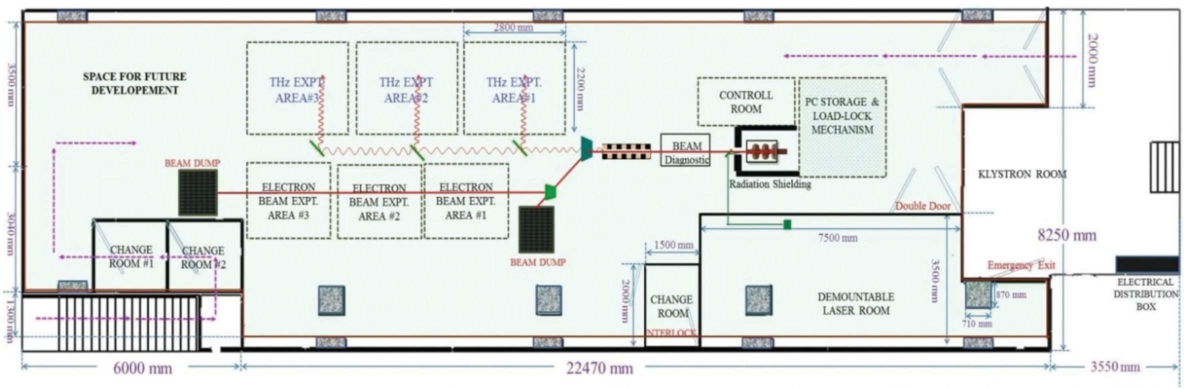

Fig. 3.1.34 IUAC FEL facility: beam hall tentative layout

C. High Current Injector (HCI) Facility (comprising of the high temperature superconducting electron cyclotron resonance ion source (HTS-ECRIS called PKDELIS))

The Site approval has been sanctioned. The design & construction approval application will be submitted soon. Shielding calculations are under way for the tentative layout shown in fig. 3.1.35.

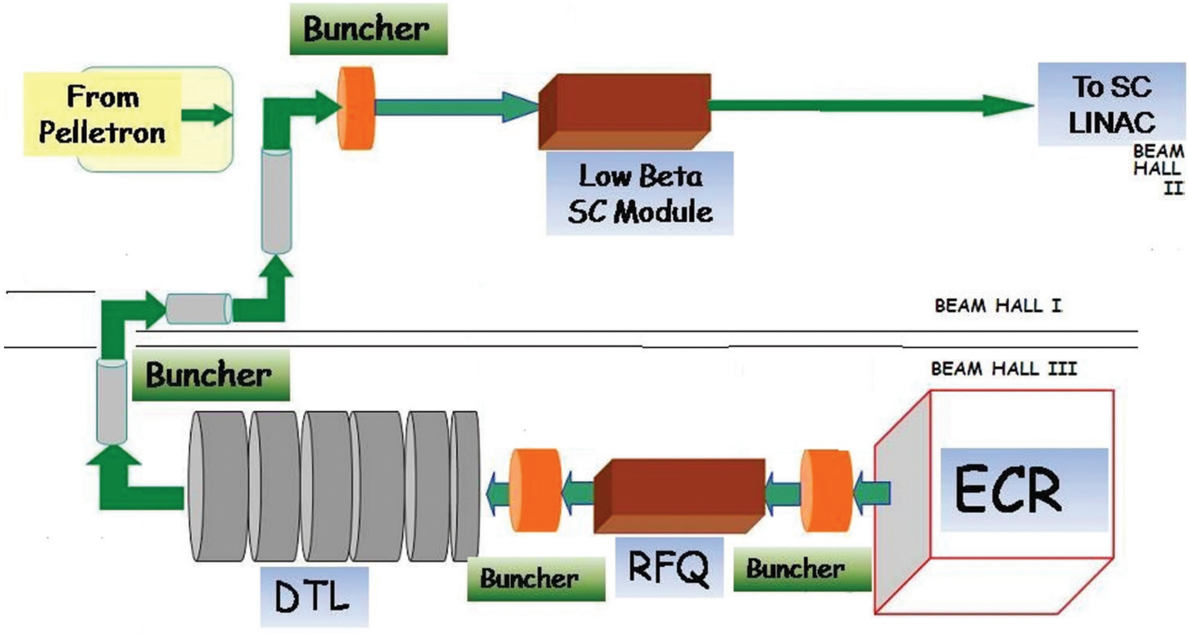

Fig. 3.1.35 IUAC HCI facility: beam hall tentative layout

3.1.7.2 Registration in E-LORA facility of AERB

Debashish Sen & Birendra Singh

Electronic **L**icensing **O**f **R**adiation **A**pplications (eLORA) System is an e-Governance initiative by AERB. It is a basically a web-based application for automation of regulatory processes for various Radiation Facilities in India. The system is aimed at achieving paperless licensing of Radiation Facilities. The objective of the project is to enhance efficiency and transparency in the regulatory processes of AERB.

Once the registration of the Institute and the Radiation Professionals are done, all the correspondences with AERB become online. This saves a lot of paperwork and time. Following procedures has been carried out using this **E-LORA facility:**

- Sanction of siting, design & construction of a radiation facility
- Modification/ shifting of a radiation facility
- Informing safety status of radiation facilities at regular intervals
- providing details of the radiation monitors used in the facility along with their calibration dates and other details
- providing details of radiation sources in custody of IUAC
- procurement of new radiation sources
- non compliance of any safety measures and its rectification
- information regarding AERB inspection etc.

3.1.7.3 Remote readout facility for Gamma area monitors

Birendra Singh & Joby Antony

At present, existing panels are analog. It is being planned to make these digital as shown in fig. 3.1.36 using RS 232 communication. Exact values of the radiation levels in beam hall and tower will be available in the remote readout panels installed in the control room.

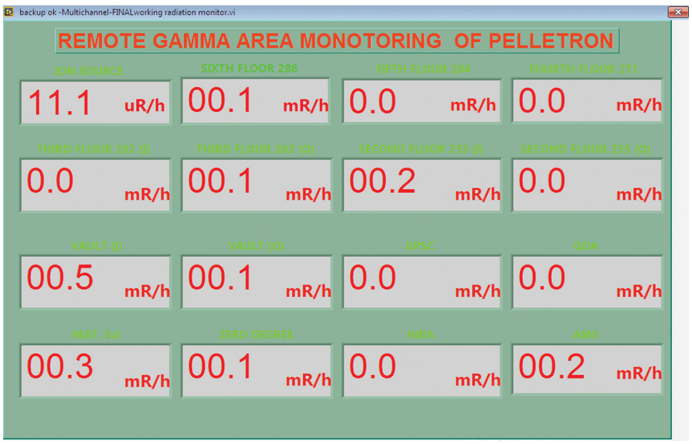

Fig. 3.1.36 Remote readout facility panel

3.1.7.4 Luminescence study of γ-ray and C^{5+} ion beam irradiated $LiCaBO_3$:Cu phosphor

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In this work, a study on some thermoluminescence characteristics of $LiCaBO_3$:Cu phosphor is presented. The samples in the form of pellets were irradiated at room temperature by a C^{5+} ion beam at energies of 75Mev for different ion fluences in the range of 15×10^{10} to 30×10^{12} ions per cm^2, using a 16MV tandem van de Graaff type electrostatic accelerator (15 UD Pelletron) at the Inter University Accelerator Centre, New Delhi, India. The full details of this set up are given by Kanjilal et al[1]. Thermoluminescence (TL) measurements with heating rate 5 K/s were taken using Nucleonix 1009I and Harshaw (3500) TLD reader. Powder samples were also irradiated by ^{137}Cs γ- source. Fig. 3.1.37(A) shows typical glow curves for the sample exposed to 1.2 rad γ-ray irradiation with a source of ^{137}Cs. TL glow curves were taken for different concentrations of Cu ion. Fig. 3.1.37(B) represents the TL glow curves of $LiCaBO_3$: Cu (0.02, 0.05, 0.1 and 0.2 mol%) phosphors. All the samples were irradiated for 1 min (3.75×10^{12} ion cm^{-2}) carbon exposure. From the Fig. 3.1.37(B) it is seen that the results are similar to that of γ-ray irradiated $LiCaBO_3$: Cu; as TL output goes on increasing with the increasing Cu concentration but then it gets quenches at 0.1 mol%.

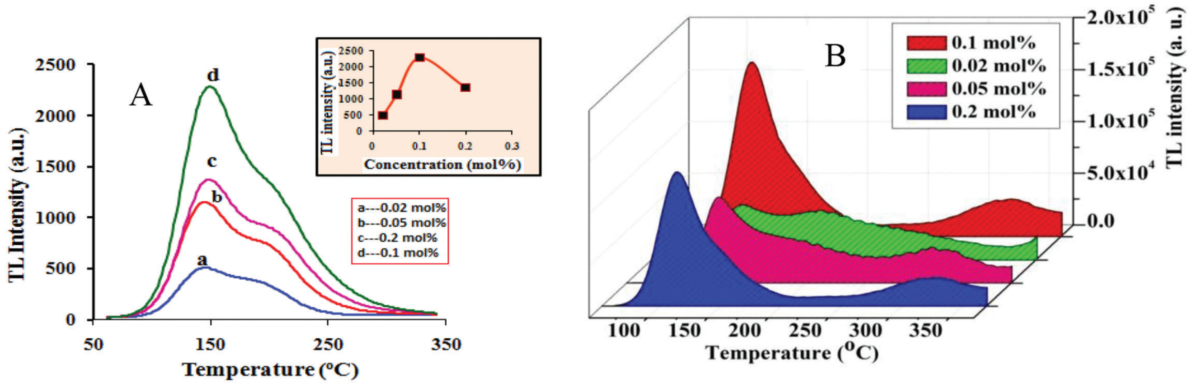

Fig. 3.1.37(A)TL glow curves of $LiCaBO_3$:Cu phosphor exposed to 1.2 rad γ-ray exposure,
(B)TL glow curves of C^{5+} ion beam irradiated $LiCaBO_3$:Cu phosphor exposed for 3.75×10^{12} ion cm^{-2}.

The glow peak nature is almost same for different concentrations except for the lowest concentration (0.02 mol%). From the glow curves, it can be noticed that the prominent peak is at lower temperature side and also varying for different concentrations. For lowest Cu concentration prominent glow peak is noted at 117 ºC with a small hump at higher temperature 177ºC. For 0.05 mol% Cu concentration glow peak has shifted to 125 ºC with a small peak at 295 ºC. For both 0.1 and 0.2 mol% Cu concentration main peak has again shifted to 113 ºC with a small peak at 317 ºC.

REFERENCES

[1] D. Kanjilal, S. Chopra, M. M. Narayanan, I.S. Iyer, J. J. R.Vandana, S.K. Datta, Nucl.Instrum. Methods A 328 (1993) 97-100.

3.1.7.5 A comparative investigation of Ce^{3+}/Dy^{3+} and Eu^{2+} doped $LiAlO_2$ phosphors for high dose radiation dosimetry: Explanation of defect recombination mechanism using PL, TL and EPR study

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In this work thermoluminescence characteristic of RE ($Ce^{3+}/Dy^{3+}/Eu^{2+}$) activated $LiAlO_2$ phosphors have been studied. Phosphors were synthesized by solution combustion synthesis method. The thermoluminescence study was carried out for γ-ray irradiation using GC-1200 ^{60}Co gamma exposer at IUAC, New Delhi. TL reading was detected with the help of Nucleonix 1009I and Harshaw (3500) TLD reader at a constantheating rate of 5 ºC/sec.The TL glow curve of $LiAlO_2$ phosphor at different concentration of Ce^{3+}/Dy^{3+} and Eu^{2+} is shown in Fig. 3.1.38. The variation in TL intensity was observed as the doping concentration varies from 0.1 mol% to 1 mol%

but maximum intensity was found to be at 0.3 mol% and 0.1 mol% of Ce^{3+} and Dy^{3+} ion concentration (Fig. 3.1.38 a, b). Eu^{2+} doped $LiAlO_2$ phosphor shows maximum TL intensity for the doping concentration of 1 mol% (Fig. 3.1.38 c). As the doping concentration increases from 0.1 mol% to 1 mol%, the corresponding TL intensity was found to increase predominantly. This certifies that in TL process Eu^{2+} plays an important role in creating defects. A slight variation in TL peak temperature position was observed for different doping concentration. The inset of Fig. 3.1.38 c shows the TL glow curve of un-reduced $LiAlO_2:Eu^{3+}$ sample. The nature of TL glow curve is quite similar with the Ce^{3+}/Dy^{3+} doped sample. The TL intensity is also very less as compared to Eu^{2+} doped $LiAlO_2$ phosphor. The glow curve nature of both $LiAlO_2:Eu^{3+}$ and $LiAlO_2:Eu^{2+}$ suggests that the enhanced TL intensity and change in glow curve structure is due to the reduction of Eu^{3+} to Eu^{2+} ion. In our study the TL glow curve of un-doped $LiAlO_2$ phosphor gives a single dominant peak at 236 ºC while in previous reported studies the dominant peak was observed at 105 ºC after X-ray irradiation[1]. The change in structure and prominent TL peak position suggest that the trapping and recombination efficiency depend also on the irradiation type used. Since the γ-ray radiation has a greater energy value than X-ray radiation the irradiation of sample with γ-ray radiation will create deeper trap than X-ray radiation.

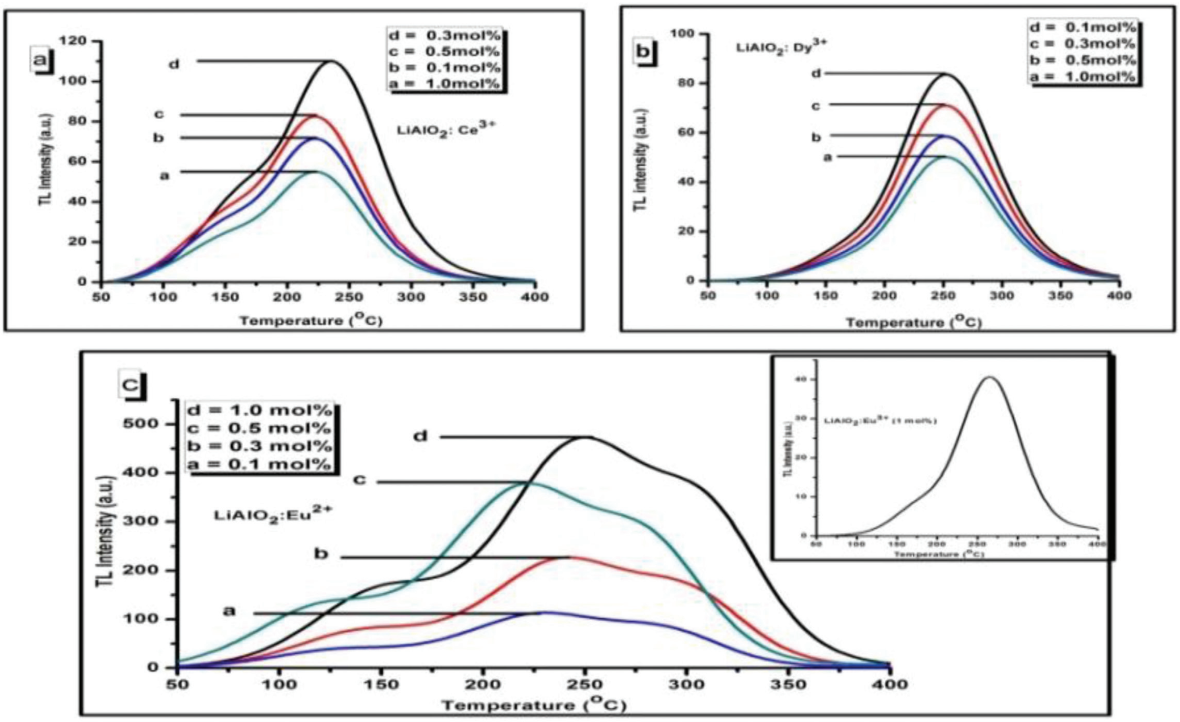

Fig. 3.1.38 TL glow curve for different concentration of **a)** (0.1-1.0 mol%) Ce^{3+}
b) (0.1- 1.0 mol%) Dy^{3+}c) (0.1-1.0 mol%) Eu^{2+} (inset Fig. shows the TL glow of 1mol% Eu^{3+} doped $LiAlO_2$ phosphor)

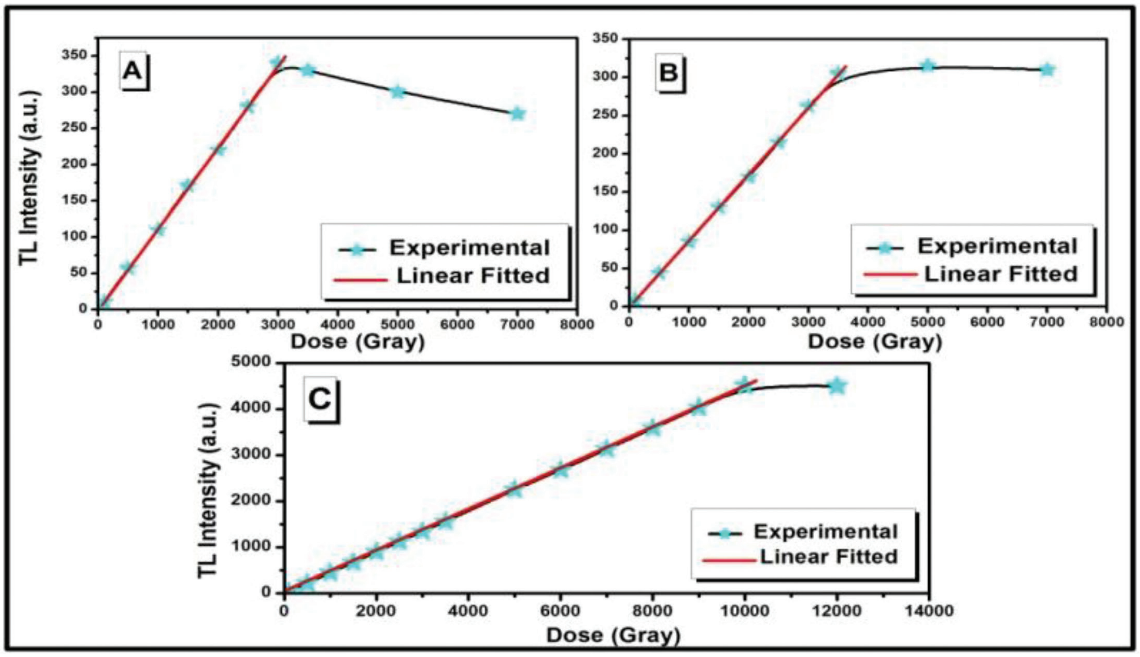

Fig. 3.1.39 TL dose response curve of A) $LiAlO_2:Ce^{3+}$ B) $LiAlO_2:Dy^{3+}$ and C) $LiAlO_2$: Eu^{2+} phosphors.

The TL dose response curve of Ce^{3+}/Dy^{3+} and Eu^{2+} doped $LiAlO_2$ phosphor is shown in Fig. 3.1.39. All TL materials are irradiated within the dose range of 1 kGy to 12 kGy. For Ce^{3+} doped $LiAlO_2$ phosphor linear response was observed up to 3 kGy whereas for Dy^{3+} doped $LiAlO_2$, linear response was observed up to 3.5 kGy and after that saturation starts. Fig. 3.1.39 c shows the dose response curve of Eu^{2+} doped $LiAlO_2$ phosphor. This $LiAlO_2:Eu^{2+}$ phosphor shows a linear dose response up to 10 kGy and after that saturation appears. Thus, as synthesized phosphor can be used in food radiation dosimetry and in other high radiation dosimetry areas.

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3.1.7.6 Study ofthermoluminescence property of C^+-ion doped anodized alumina

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The application of thermoluminescence (TL) has created immense interest due to their potential to determine radiation doses for food-safety, radiation therapy, personal dosimetry, environmental monitoring, etc. However, the performance of a phosphor relies on thermally stimulated light emission from luminescent centres created during the exposure to an ionizing radiation. Aluminum oxide (Al_2O_3) is one of the promising materials for dosimetry. Although this material was forgotten for a long time due to its low sensibility compared with that of TLD-100, it recently regained interest owing to the development of anion defects in Al_2O_3:C single crystals. It was reported to be highly sensitive, even more than TLD-100, though conventional crystal growth technique requires high temperature in the presence of a high tumbling atmosphere. Nevertheless, the TL sensitivity of crystalline Al_2O_3 can be enhanced by doping with carbon, but this is only good for low dose radiation monitoring (typically 0.1-100 Gy). Interestingly, a prominent TL sensitivity can be achieved from nanocrystals with increasing surface-to-volume ratio because of increasing surface states. Therefore, judicial use of Al_2O_3 nanocrystallites will give a fertile ground for offline dose monitoring. The nanotrenches of anodized alumina in this respect can also give additional path for improving efficiency, which can be enhanced further by controlled introduction of C in Al_2O_3 matrix. Since ion beam implantation is known to be a powerful method because of its ability to control over distribution of dopants and residual defects, it is therefore important to understand the impact of C^+ ions in controlling the formation of traps in anodized alumina and also to explore its suitability for ion beam dosimetery by following the TL glow curves with increasing fluence (i.e. ions/cm^2).

To execute this plan, after optimizing the porosity, the penetration depth of C^+ ions in Al_2O_3 layers have been calculated by SRIM. Typical porous structure in the present set of samples is shown in Figs. 3.1.40 and 3.1.41. Based on this understanding, the anodized alumina has been exposed to 50 keV C^+ ions in the fluence range of 2.33 x 10^{15} to 1.3x 10^{16} ions/cm^2. Following the initial structural analysis by XRD, TL response of the ion irradiated samples was characterized, showing a systematic rise in intensity with increasing fluence. For understanding of the underlying process, the anodized alumina before and after irradiation have now been studied by various techniques, like SEM, TEM, XRD, RBS and XPS.

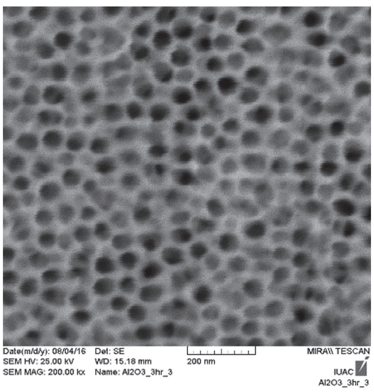

Fig. 3.1.40: Plan-view SEM image showing porous anodized alumina

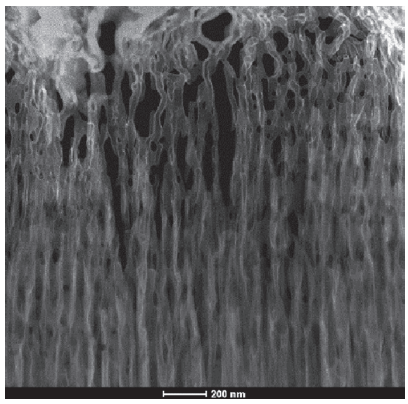

Fig. 3.1.41: Cross-sectional HAADF image showing trenches in anodized alumina

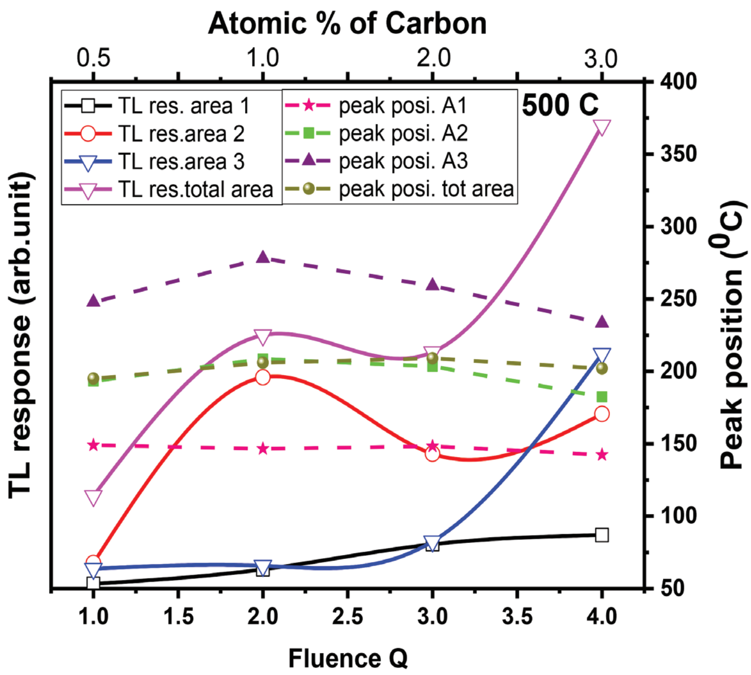

Fig. 3.1.42: TL response (superimposed with fitted data) after C^+ implantation with various fluences (Q in ions/cm^2).

3.1.7.7 Optimization and Thermoluminescence Study of the Nanophosphor $BaSO_4$:Eu

Kanika Raheja[1], A. Pandey[1], Shaila Bahl[2], Pratik Kumar[2], D. Sen[3] and Birendra Singh[3]

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In this work, first and foremost optimization of the nanocrystalline $BaSO_4$:Eu has been presented by primarily varying the concentration of the rare earth element Europium (0.05, 0.10, 0.20, 0.50 and 1.00 mol %). Further, a comparative study of the nanophosphor with a well-established dosimeter i.e. TLD-100 (and by extension to $CaSO_4$:Dy (TLD-900)) has also been reported here as a step towards finding an ideal TL dosimeter. The various batches of the said phosphor prepared by the chemical co-precipitation method have been investigated for their TL sensitivity property and it has been observed that $BaSO_4$:Eu doped with 0.20 mol% Europium showed the highest sensitivity out of the lot. Moreover, when compared to the standard dosimeter, the optimized $BaSO_4$:Eu (0.20 mol%) showed a higher sensitivity of about 28.52 times that of the Standard TLD-100 and 1.426 times higher than standard $CaSO_4$:Dy (TLD-900). An extraordinary linear TL response curve over an extensive range of doses (10Gy to 2kGy) is yet another integral factor that makes the current phosphor quite promising for dosimetric purposes. Lastly, the optimized sample has been characterized using X-ray Diffraction (XRD) method.

This work was presented in 61st DAE Solid State Physics Symposium, KIIT University, Bhubaneswar, Odisha, as a poster presentation.

3.1.7.8 Nanocrystalline Europium Doped Barium Sulphate as an Energy Independent Thermoluminescent Dosimeter

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[2]Medical Physics Unit, IRCH, AIIMS, New Delhi 110029, India.
[3]Inter-University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi 110067, India.

Nanocrystalline $BaSO_4$:Eu was prepared by the typical chemical co-precipitation method and was characterized using X-Ray Diffraction(XRD). The nanocrystalline sample thus prepared was further separated into two different groups which were each divided into separate packets. One of the groups was exposed to a radiation range from 10Gy to 300Gy of gamma using 1.25 MeV of Co-60, while the other group was irradiated with 1Gy to 300Gy of gamma using 662 keV of Cs-137. Thus, it was made sure that both the groups had an overlapping range of doses from 10 Gy to 300 Gy for different energies of radiation. At this point, it was observed that the shape of the glow curves remained astonishingly similar for different energies of radiation. Moreover, on studying the TL response curve, it was established that the response curve for the present nanophosphor showed little variation even after changing the energy and source of the gamma radiation. Therefore, it can easily be concluded that the present nanophosphor displays huge potential as an energy independent thermoluminescent dosimeter.

This work was presented in 61st DAE Solid State Physics Symposium, KIIT University, Bhubaneswar, Odisha, as a poster presentation.

3.1.8 Data Support Laboratory

Ruby Santhi, Rajesh Nirdoshi and P. Sugathan

Data Support Laboratory provides support on data acquisition & electronics setup during experiments. In data room, two CAMAC based on-line data acquisition systems are running with 'freedom' software using CMC 100 controllers. There were few occasions in the current year when online Data Acquisition Systems caused problems due to large amount of stored data causing problems to open the other applications. The problem has been sorted out immediately by removing unwanted stored data and providing enough free space. Apart from providing regular user support and maintenance of the setup, few electronic modules have been developed and some existing modules serviced. The lab also procures required electronic modules, co-axial connectors and cables required for user support.

3.1.8.1 Development of Electronic Module

VME based NIM-TTL Module

Ruby Santhi, Kundan Singh

A new VME (Versa Module Europa) module eight channel NIM-TTL has been developed at IUAC as shown in fig. 3.1.43. This Module is a 1-unit wide VME module that can work either as 8 channel general purpose I/O Register or as NIM-TTL. The operating mode is selected via VME and is signaled via front panel LEMO connectors. The module has 8 NIM Outputs. Individual channel enabling/disabling through Software Input/ output generation. The complete VME registers and control logic of VME bus operation is designed and implemented on single Xilinx's Spartan 3 FPGA. The firmware for the Slave interface logic is written in VHDL (Hardware Description Language) and tested.

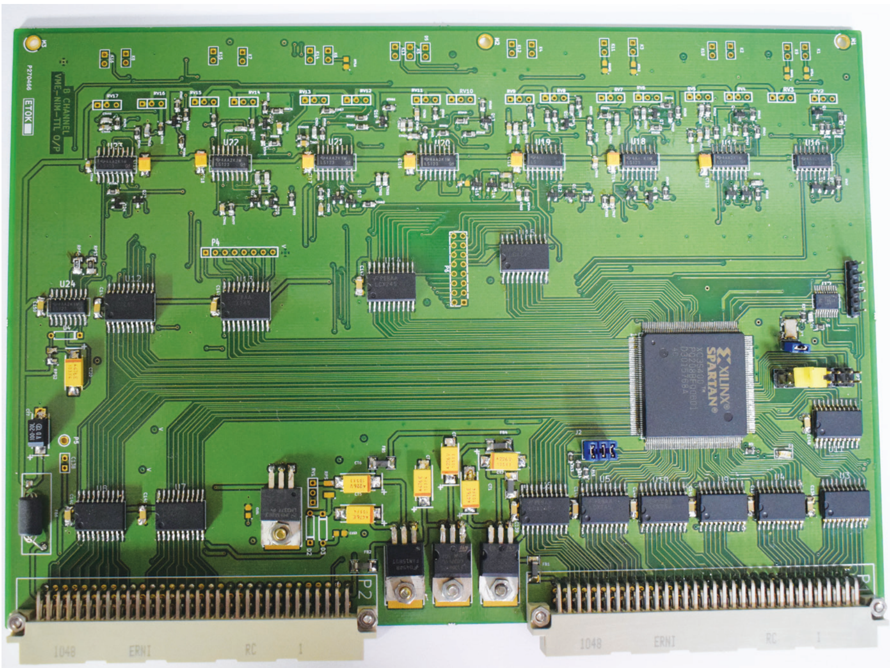


Fig. 3.1.43 The module can be used in VME based data acquisition for generating BUSY I/O signal.

3.1.8.2 MIDAS GUI tested with VME DAQ

Ruby Santhi, Kundan Singh

MIDAS (Maximum Integration Data Acquisition System) is a modern data acquisition developed by PSI and TRIUMF (https://midas.triumf.ca) that that supports VME based acquisition system. It has been tested with Scientific Linux 6.5 with the ROOT and other packages. It currently supports V2718 (optical link bridge and V1718 USB based Bridge) CAEN V785 ADC, V775 TDC and V862 QDC and V830 scalar modules. We tested our VME DAQ using MIDAS and collected spectra from different radiation sources and compared with Freedom DAQ. Software parts were modified for readout of CAEN **V785N** 16 Channel Multi event Peak Sensing ADC assigned in MIDAS and tested by collecting spectrum from Cesium Source.

3.1.8.3 New Target Thickness measurements setup for Target Lab Facility

Ruby Santhi

Thickness measurements of thin targets fabricated in our target laboratory are performed using alpha particle energy loss measurement. For this purpose, a high resolution MCA setup running on UBUNTU operating system has been installed which uses Freedom software for display and analysis of the spectrum. The PC is connected to the hardware through USB port. The setup has been successfully used in measuring thickness of the rolled targets viz. ^{175}Lu, ^{159}Tb, ^{169}Tm etc. along with few Aluminum catcher foils.

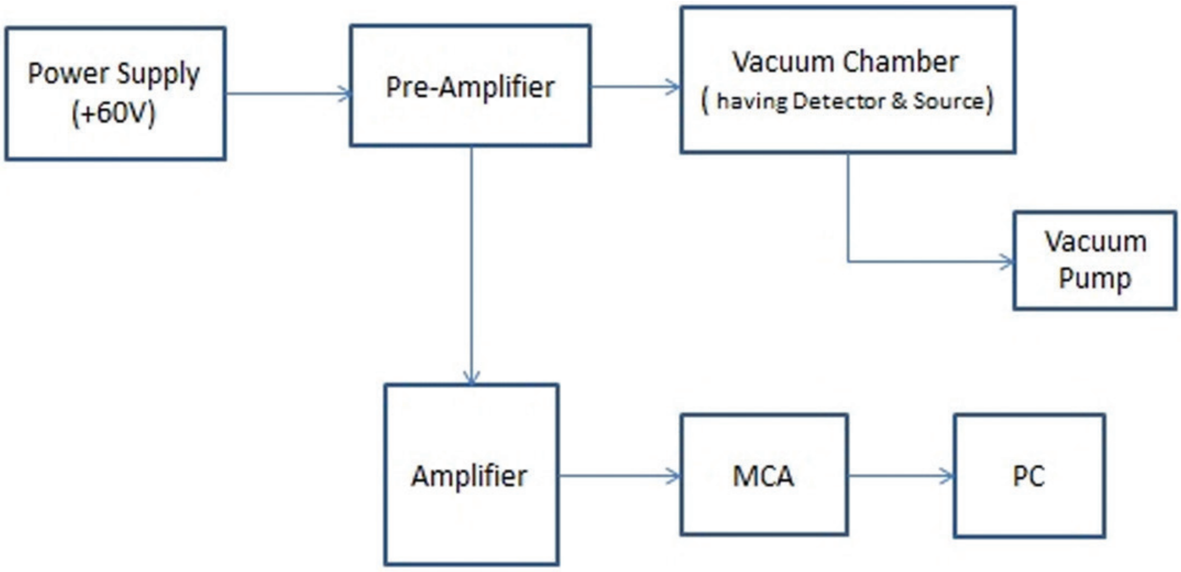


Fig. 3.1.44 Block diagram of new target thickness measurements setup

3.1.8.4 Data Acquisition program with Wiener CC-USB crate controller

Ruby Santhi

The CCUSB is a full-featured CAMAC crate controller with integrated high speed USB-2 interface and full CAMAC dataway display. It supports Master and Slave operations also. The DAQ program relies on libxxusb library provided by the manufacturer (Plein & Baus GmbH) for the communication with the crate controller. The CERN ROOT libraries are used for the GUI, monitoring and storage of the data. When program is started, the program will look for Wiener crates at USB ports of the computer and connect to the first CC-USB crate found, or report an error if no crates were found. 2ADC and 2 TDC tested with Radiation sources, and a spectrum is shwon in fig. 3.1.45 with ^{137}Cs source.

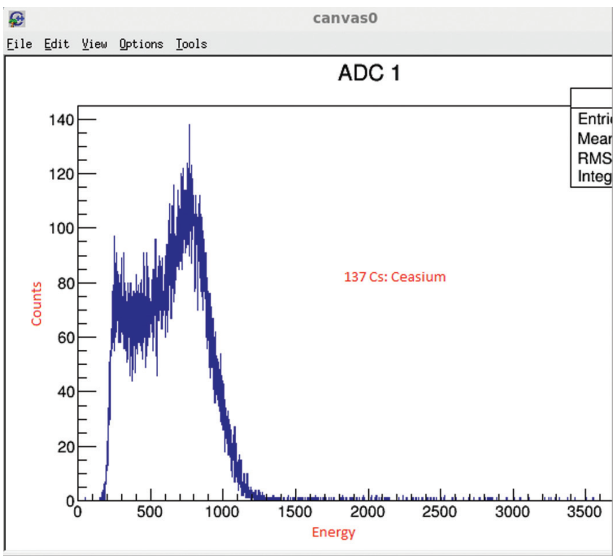


Fig. 3.1.45

3.1.8.5 PID based Detector Gas Flow Controller Design

Rajesh Nirdoshi, Joby Antony

A PID (Proportional-Integral-Derivative) based gas flow controller (fig. 3.1.46) is designed whose aim is to control the gas pressure inside a detector. It consists of three basic parts namely, pressure sensor, controller & control valve and a system whose pressure is to be controlled (detector in our case). We used MKS 248A valve, MKS 626B pressure transducer. Initial testing was done with MKS 250E pressure/flow control module. Later on, all the tests were repeated with our commercially designed controller. It has a gain (0.2% to 100%) and phase lead (0.05sec to 10sec) adjustment capability for optimized closed-loop control. Open loop and closed loop control operations were successfully performed and a control accuracy of +/- 0.25 Torr in 100 Torr is achieved.

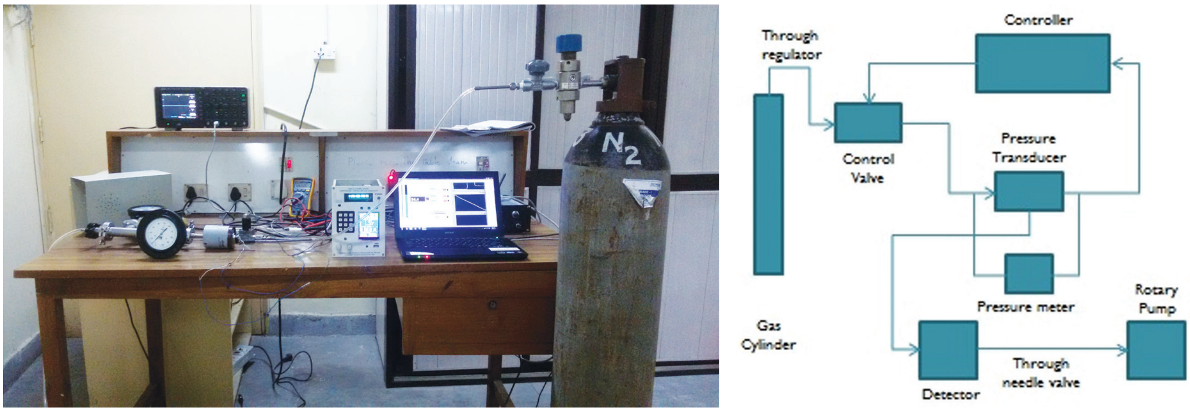


Fig. 3.1.46 (Left) Photograph and (Right) block diagram of PID based detector gas from controller.

3.1.8.6 Ethernet Enabled Stepper Motor Controller

Rajesh Nirdoshi, Joby Antony

An Ethernet based stepper motor controller (fig. 3.1.47) is designed to remotely control the target ladder in NAND. Various functions are provided on to the front touch panel like distance (in mm), start/stop control, reset, direction etc. The input supply voltage of the motor driver is in the range of 12V-50V and it has selectable micro-steps up to 20000 steps per rotation for a 1.8deg stepper motor. More features are to be added as per the requirement.

Fig. 3.1.47 Photograph to ethernet enabled stepper motor controller

3.1.8.7 Servicing and Maintenance

Following modules have been serviced and made operational

- TAC/ SCA module, EG&G Ortec model 567
- Philips Scientific 7126 16-channel level translator

Following modules are added to data acquisition resource pool:

- TFA ---Part No 2111
- TSCA Part No 2037A
- Philips 7164 ADC, 1k Ohm input impedance - 2nos.
- Philips 7186 TDC, 400ns - 2nos.

3.1.9 Computer and Communications

S. Mookerjee, E.T Subramaniam, S. Bhatnagar and I. Satpathy

The major activities this year include the installation of a secure wireless network covering all office blocks, guest houses and hostel, an overhaul of the internet access and security hardware and software systems, the expansion of the Centre's local area network, enhancement and consolidation of the Centre's enterprise computing and administration database package, incremental addition to the software and user base of the IUAC high performance computing facility, an overhaul of the IUAC data acquisition area and a new optical fibre based data acquisition network, and progress in the development of new DSP-based data acquisition hardware and software.

3.1.9.1 Local area networks and servers

A new wireless network, covering six office and laboratory buildings, two guest houses and the hostel buildings was implemented this year. The new network consists of 48 wireless access points capable of gigabit bandwidths, 12 PoE network switches dedicated to the serving these access points, a new optical fibre network connecting the PoE switches, and a central controller for authentication, security and single-pane administration. The wireless network is designed to serve hundreds of simultaneous users, including mobile users, and is expected to cater to future internal communications needs, including IP telephones and video meetings. The implementation process was seamless, with no downtime required for the existing wired and wireless networks. With this network, a single sign-on enables users to connect to the IUAC network infrastructure from all connected buildings.

The wired gigabit network was also significantly enhanced this year. Besides about 50 network points added as part of the routing expansion in existing buildings, a hundred and thirty network points were added in the new second floor of the main laboratory building. The IUAC wired non-blocking gigabit network now consists of twenty one edge switches and over a thousand network nodes.

The internet security infrastructure at IUAC has hitherto consisted of a Linux-based software firewall, configured and updated manually in-house. A new UTM system capable of session-based authentication was added this year. The new system serves the expanded wireless network. It is capable of handling more than two hundred simultaneous sessions, and has a web-based administration interface while keeping all security features of the software firewall.

The IUAC mail server was upgraded this year to a new version of Postfix and Dovecot. To add new features including shared calendars and collaboration tools, ease mail server administration and enhance security, it is proposed to shift the IUAC mail system to a robust Linux/Zimbra based solution. The evaluation of the proposed solution was completed this year, and an order placed. The solution is expected to be in place by August 2017.

3.1.9.2 High Performance Computing Facility

In 2008, the Department of Science and Technology sanctioned a grant of Rs. 13.54 crores to set up a high performance computing facility at the Inter University Accelerator Centre. The purpose of the grant was to provide a major computing facility for faculty and students of universities and colleges across the country. The facility has been operational since 2010, and now serves more than four hundred users from a hundred and forty research groups in colleges, universities and institutes across the country.

While the facility is still heavily used, with a typical load of twenty parallel and a hundred serial jobs running and as many in a wait queue, the computer servers are reaching end of life, and the cooling systems require an overhaul. The cooling facility consisting of four 33 TR water chillers and sixteen heat exchange modules was revamped, with the addition of one new chiller. Proposals for a refresh and enhancement of the facility were submitted to funding agencies. Meanwhile, twenty new users started using the facility this year.

3.1.9.3 New generation Instrumentation & Acquisition System

E.T. Subramaniam, Kusum Rani and Mamta Jain

Up-gradation of the DAQ analysis package ‘CANDLE’:

CANDLE is an online and offline data analysis package being used at IUAC. The entire CANDLE code has been modified this year, to make it universal for 32 bit and 64 bit computers. After testing the stability of the code for both the architectures, the new version of CANDLE has been uploaded to the IUAC web server, and is now the supported standard.

Among the enhancements made to the CANDLE code, a Radware compatible 'CUBE' can now be generated, read, written and projected on to a matrix. Based on the memory available, the user can choose a cube size, by using the CANDLE option '--cubelength, -c'. By default the size is 1400x1400x1400 (which uses 1.7 GB of RAM), but is extendable up to 2400x2400x2400 (which uses 8.6 GB of RAM).

Time gated matrix and cube can also be generated. That is, every event is unfolded and the corresponding time is unfolded and cross checked with the user given timing conditions for event validation.

Complete auto calibration of all the visible spectra can be done at once by reading a source file containing energies, and based on that each and every histogram is looked into and calibrated providing the coefficients of the quadratic. The initial guess of the calibration (linear) is iteratively computed till the error is minimized. The quadratic fitting is done using the Levenberg-Marquardt method. This code is adapted for CANDLE almost verbatim from code kindly made available by Dr. Rudrajyoti Palit's group, TIFR, Mumbai.

Incremental improvement in ERP:

Continuously evolving needs of IUAC's ERP system, which forms the backbone of administrative processes in the Centre, require modifications in the existing program. Suggestions provided by the ERP committee in this context have been implemented. Some problems in printing have also been sorted out. The package was extended to provide more classes of information required by administration.

Among additions to the package, code to e-mail the agenda for Purchase Committee meetings to members has also been incorporated. Write-off of assets has been implemented in the code successfully.

Mass production and insitu testing of GEM:

Zero delay timestamp, incorporated in GEM as a new feature, has successfully been tested in INGA beam hall. This added feature may be useful for Multi-Strobe-Multi-Crate DAQ systems, so a larger number of GEM modules will be needed in future. Keeping this in mind, mass production of GEM was planned and ten modules have been completed. Burning test (72Hrs continuous run) has been done for seven modules on the test bench, putting the modules in various configurations like Single Crate, Multi-Crate, and Multi-strobe Multi-Crate DAQ systems. Round Trip Time between two modules has also been calculated and tested using different length of UTP cables.

Beam Profile Digitizer:

The Beam Profile Digitizer module, placed at the high voltage deck at HCI beam hall with the supporting software installed in the computer at control panel, has been tested and given to user. Taking the user inputs, like simultaneous access to eight BPMs, into account, the requirements of the circuit have been studied. Earlier, two out of twelve BPMs could be selected and seen at a time. Display update time is another factor is taken into consideration to minimize the dead time.

Time stamp for heterogeneous systems:

If heterogeneous systems are to be synchronized, which can accept an external 100MHz clock and time stamp the generated event so the event of both systems can be correlated later, an intermediate module is required. Using the time stamping feature of GEM, possibilities of synchronization between TIFR digital DAQ and CAMAC DAQ have been explored and simulated.

Upgradation of Data acquisition PC:

Some of the data acquisition PCs have been replaced by Ubuntu based rack mounted all-in-one PCs. The existing data acquisition setup has been tested with the new PCs.

The VME based 24 channel FDC: Design and testing:

A Frequency-to-digital converter module with VME form factor has been designed and developed to serve the requirement of control system of super conducting linear accelerator at IUAC. This module is used to measure the frequency difference of master clock and the resonator frequency digitally with a computer using VME interface. This digital frequency data is used to tune and phase lock the cavity (resonator). Later this digital data of frequency difference (phase error) can be used for auto tuning of super conducting LINAC.

The module has two FPGA, one is programmed for VME back plane interface and another is for frequency to digital conversion. The main specifications of the module are the following:

Number of channels	:	24 (all the three cryostats served)

Input signal amplitude	:	+/- 15V
Frequency range	:	0 to 100 kHz
Resolution	:	1Hz
Readout	:	22bit/16bit

The module has been tested with working LINAC.

Configuring the DAQ network:

A comprehensive overhaul of the data acquisition network connecting the data acquisition systems in the experimental areas and the data room was undertaken this year. The new network completely replaces the old 100 Mbps UTP network with a gigabit star network with fibre connectivity from core to edge switches, and gigabit copper from edge to node.

The core switch, in the data room, is connected to four edge switches in Beam Halls 1 and 2, to serve the GDA, INGA, HIRA, HYRA, GPSC, NAND, Material Science and Radiation Biology experimental areas. The switches are configured to ensure security and isolation from the main IUAC network.

3.2 UTILITY SYSTEMS

3.2.1 ELECTRICAL GROUP ACTIVITIES

U. G. Naik, Raj Kumar

This group is primarily responsible for maintaining the electrical installations of IUAC and also to develop adequate electrical infrastructure for the upcoming scientific projects. The uptime achieved for electrical systems was close to 100%. This was possible with judicious maintenance schedules and monitoring arrangements. This group has also successfully completed the projects and works envisaged for the year F.Y.2016-2017.

MAINTENANCE ACTIVITIES:

3.2.1.1 Maintenance of electrical installations of substation, office blocks and residential colony

Maintenance of electrical installations is managed through the AMC with external agency, however all the consumables required are supplied by IUAC. M/s KBS Electricals was engaged for AMC financial year 2016-17 who have carried out the maintenance in appreciable manner.

There was not even a single event occurred for the transformers or any switch gears related to transformer HT and LT. Charging motor of one of the distribution ACB at downward level got broken and supply to UPS input got tripped. This resulted in failure of Helium Compressor and loss of helium gas. Steps are taken to minimize such failures in future. There are many maintenance activities routinely carried out however few major activities are listed below.

- Dehydration of transformer oil for 7 Transformers- (4500ltrs)
- Periodic maintenance of LT panels, Distribution boards and other accessories, Lighting, Fixtures, lighting and power circuits.
- Servicing of 3nos of DG sets 750kVA -twice a year.
- Maintenance of street lighting and earthing.

3.2.1.2 Captive power installations

Institute had a captive power base of 2500 kVA. Three DG Sets of 750 kVA are synchronized and take care of 15UD Pelletron, He Plant and HPC Data Centre. The group has shown ever readiness in running the systems round the clock O&M activities within short period if need arises. Not even a single failure has been observed during the year. Yearly maintenance is being carried out through service from the manufacturer. During the current year, Power command card of 750kVA DG#1 has gone bad and had been replaced with new one by Cummins.

3.2.1.3 Voltage stabilisers

Voltage stabilisers supporting the insatllations having capacities from 30 kVA to 1000 kVA are working in healthy conditions with practice of periodic maintenance and have kept 100% up time. No failure occurred during the financial year.

3.2.1.4 UPS Installations

IUAC has 10*60 kVA UPS, 3*300 kVA, 4*200 kVA, 1*50 kVA and around 20 nos. of 2-10kVA UPS systems maintained by electrical group. These are under supervision and control of this group. Although the day to day operations is carried out by electrical group the comprehensive AMC order have been placed on the manufacturer for all the sets out of warrantee period. Batteries worth ₹ 3.50 lakhs were replaced for UPS during the FY 2016-17

3.2.1.5 Power Factor Compensation

Electrical group is very happy to declare that yet again we achieved average power factor of 0.98 lag throughout the year. Our system power factor without correction is about 0.85 and by raising it we saved around Rs.150 lakhs through the year from energy billing.

3.2.1.6 Communication Equipments

Electrical group maintains the 14 hand held radio stations (Walkie-talkie) and one base station. The routine maintenance such as replacement of batteries, antennas, switches etc is managed by this group. This year we have given AMC for service to the authorized agency of MOTOROLA @ cost of ₹ 25000/- per annum. The group takes the responsibility of getting the revalidation of license periodically from the Ministry of telecommunications.

3.2.1.7 Fire detection and alarm system

Electrical group has been maintaining fire detection & alarm system covering whole lab complex and new guesthouse. This system has been extended in Beam Hall-II stores areas. Renovation of fire detection system has been done in Beam Hall-III as this system was giving lots of troubles. All parts of the system were maintained in good health throughout the year.

PROJECT WORKS:

3.2.1.8 Electrical works for High Current Injector (BH-III)

Electrical group has prepared technical specifications, tender NIT for the electrical requirements of high current injector and all the beam line components of bean hall -III. Present status is 50% of materials are delivered and rest 50% will be delivered by mid of July 2017 and all works will be completed by end of July 2017.

3.2.1.9 Roof top solar system for IUAC

Electrical group has prepared technical specifications, tender NIT for the roof top grid interactive 2*50 kWp solar power generation plant, to be installed on roof top of main lab building and roof top of Auditorium building. Present status is 100% of materials are delivered and installation is in progress. This project is likely to be completed by end of July 2017.

3.2.1.10 Compound lighting

Lighting inside campus around ladies hostel and new guest area has been improvised by installing LED post top lights on 3mtr high light poles.

In the same manner a lighting scheme has been worked out for the lighting around newly built auditorium using LED light fittings. All the materials have been delivered and the entire lighting works will be completed by end of July 2017.

3.2.1.11 Electrical works for XRD and SEM facilities in LAB-2

Electrical group have created a electrical infrastructure to over all the equipments of XRD and SEM facilities after close coordination with the user. Special requirements of clean earth and power isolation have been achieved by installing chemical earthing and isolation transformers at strategic locations.

3.2.1.12 Renovation works

Electrical Group has meticulously planned and got the vacant flats renovated for electrical wiring and fittings as these have outlived their life cycle. Overall around 6 flats have been renovated.

3.2.1.13 Special dedicated grouping for Free Electron Laser Related Facility

Electrical group has designed & installed dedicated grounding system for free electron laser facility. Specially designed TRIAXIAL earth conductors as shown in figure were installed for high power Klystron and connected to copper chemical electrodes. Inner conductor was connected to two chemical electrodes connected together to achieve minimum resistance. The first & second shield were connected to separate copper earth electrodes. Two such tri-axial conductor based dedicated earth points are created one for Klystron & Modulator and other for photo cathode.

Similarly CO-AXIAL earth conductors were designed and installed for other related facilities of Delhi Light Source.

3.2.2 AIR CONDITIONING, WATER SYSTEM AND COOLING EQUIPMENTS

Piyush Gupta, A. J. Malyadri, Bishamber Kumar

AC SYSTEM / Cooling Equipment

IUAC's central air conditioning / low temperature system of Phase-1 consisting of 2x200 TR + 3x100 TR Central AC plant performed with 100% uptime. One 100 TR plant was put out of operation due to the fact that it was economically unviable to be repaired. Maintenance ensured that the safety record of the plant was maintained at 100% and the power consumption kept at optimum level. 2x200 TR chillers installed in 2013at an expenditure of INR 10 million have run for 17000 hours each. Other rotary equipment logged in 202,000 continuous run hours. It is relevant to note that the Indian industrial norms specify a life of ~25,000 run-hours for compressors and ~50,000 hours for other rotating equipment. Also, the Phase-II&III, screw chiller based central AC plants performed to an uptime of 100%. Phase II centrifugal chiller was replaced by a screw chiller at an approximate expenditure of 4.5 million INR. The highlight of the operation and maintenance of the above systems was the in-house supervision provided to the contracts. The yearly maintenance costs were 11.07% of ARV (Asset Replacement Value). The MTBF for all the equipment were within acceptable norms. The equipment entered into their twenty-seventh year of sustained operations and have far outlived their economic lives, yet have high availability. The approximate cost of operation and maintenance of the system was INR 9 million.

WATER SYSTEM

IUAC's centralized water system of Phase-I feeding low temperature cooling water having a total heat removal capacity of 115 TR performed to an operational uptime of 100%. This is due to the stringent maintenance practices, which were followed over the years. The system has overshot 156,000 hours from its expected life span. IUAC's centralized water system of Phase-II&III feeding low temperature cooling water also performed to an uptime of 100%. A strict monitoring on the water quality has ensured that the flow paths are in healthy condition. 150 KLD Sewage Treatment Plant (STP) also performed satisfactorily. The approximate cost of operation and maintenance of the system was INR 7 million.

Planned Works Carried Out During the Year

The extension works of Process Water SS Pipes was done in PARAS laboratory. Further, AC works in Gamma Irradiation Room and the Class-10000 Clean Room for FEL (Free Electron Laser) was commissioned during the year. Several replacement works, such as SPL AHU, MS Piping and 33TR Scroll Chiller for HPC facility were carried out. A meager budget of INR 100,000 was available for replacement works and, therefore, all the new works were carried out from the budgetary provisions of respective labs, and others deferred. Subsequent to installation, air-conditioning system of Lab Building 2nd floor was taken over the in the month of August 2016. The air-Conditioning installation works for the new auditorium is in progress and is expected to be completed in the coming financial year.

3.2.3 MECHANICAL WORKSHOP (MG-III)

D.K. Prabhakar, B.B. Choudhary, S.K. Saini, R. Ahuja and J. Sacharias

IUAC workshop is an ideal workshop equipped with modern machining and welding facilities to support Pelletron Accelerator, various laboratories and large number of user community.

The major facilities of the workshop are Machine shop and Welding shop.

Machine Shop (fig. 3.2.1) is equipped with a five axis Vertical Machining Centre and a CNC lathe. Apart from these, we have four conventional lathes, two milling machines and a Radial drilling machine catering to the tool room jobs. Most of these machines are of HMT make, fitted with DROs for achieving higher accuracy and better productivity. Apart from these, cylindrical grinder, tool and cutter grinder, horizontal and vertical band saw machines, etc. are also there for general requirements.

Workshop has CAD facility, Solid Works for the design and drafting purpose. It also has VISI CAM for the CAM support for the Vertical Machining Centre and CNC lathe. A portable CMM, with 1.8 m inspection area with 40µm accuracy, is there in the workshop metrology section.

Workshop has been involved in development activities of new system as well as a large-scale production of beam line components right from the inception of IUAC. Most of the beam line components used for the new beam lines was fabricated in the IUAC Workshop. Workshop continues to assist the entire in-house fabrication activities.

Welding shop (fig. 3.2.2) is having high quality TIG welding machine and equipment. Some of the TIG machines can give pulsed arc for the thin section welding. Air plasma cutter with a capacity to cut up to 40mm thickness of stainless steel is used extensively. Aluminum welding and Oxy-acetylene cutting and brazing set ups are also available. We have a micro plasma machine from Air Liquide, France for very thin section welding.

Fig. 3.2.1 Machine Shop

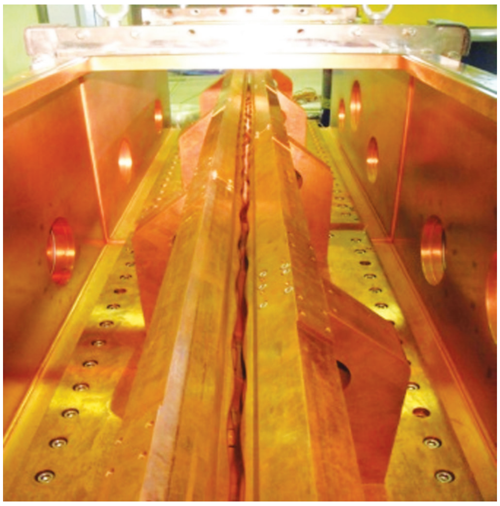
Fig. 3.2.2 Welding Shop

IUAC workshop is providing Apprentice training for the ITI passed students in both welding shop as well as in machine shop. Basic workshop training is also provided for the scientist trainees and Ph.D. students enrolled in IUAC.

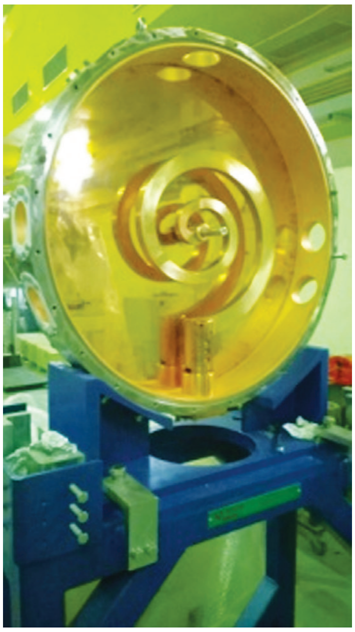
Apart from the regular workshop activities, Workshop group is involved in the following major projects/activities (fig. 3.2.3)

1. High Current Injector Development Program
   - RFQ
   - DTL
   - 48.5 MHz Spiral Buncher
2. MRI project
3. Mounting Stand for Clover Array to be used in HYRA beam line

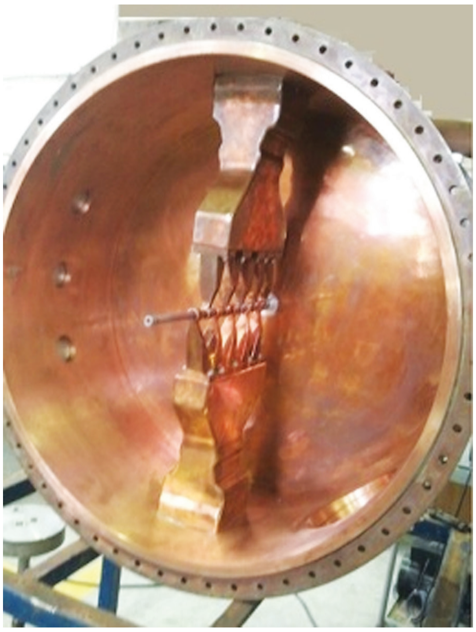
Bobbin of MRI



RFQ



Spiral Buncher



DTL

Mounting Stand for Clover Array

Fig. 3.2.3

3.2.4 CIVIL WORKS

M.K. Gupta, Harshwardhan

Works under Civil Section

- Major Projects (right now Auditorium & Main Building 2nd floor)
- Minor Projects
- Minor works
- Civil Maintenence
- External cleaning of Campus
- Liasion with outside agencies for statutory approvals and various civic problems

Important Civil Activities undertaken during the year 2016-17

Following important civil works were undertaken during the year 2016-17 in addition to routine Civil maintenance and minor works:

- Handing over and occupation of Main Lab. building 2nd floor
- Civil construction work of Auditorium (ongoing, 90% complete)
- Construction of Rain water harvesting pit in IUAC playground
- Resurfacing of all roads in IUAC campus including embedding RCC Hume pipes below roads at various locations
- Resurfacing of various existing parking spaces and development of new parking space near Sumeru II block
- Internal painting of Phase II Housing flats (ongoing)
- Fencing work around LN2 tanks area near Beam Hall III
- Renovation of Gents toilet in Main building near R.N. 203
- External & Internal painting of IUAC Main Building (ongoing)
- Covering of corridor between R.N. 6A & 7A by Polycarbonate sheet in old Guest house
- Covering of cable trench by MS chequered plates in DB rooms of LEIB building and new Guest House

- Repainting at various outdoor locations as a part of preventive maintenance work
- Making a Work Bench in RF Lab. (R.N. 229) in Main Building
- Providing & fixing Tricolour Indian Flag & light emitting finial on SS Flag pole in IUAC campus near Main Building
- P/F Hand dryers in Gents & Ladies toilets at 2nd floor of Main Building

3.2.5 COMPRESSED AIR SYSTEM AND MATERIAL HANDLING EQUIPMENTS

K.K. Soni and Bishamber Kumar (MG I)

Group is associated with the following activities:

i) **Compressed Air System:** Compressed air plant (Ph-I & PH-II) consisting of three nos. screw compressors each of 115m^3/Hr capacity, along with air dryers & filters with capacity of 3000 lpm @ 9.00 kg/cm^2 have been maintaining uninterrupted air supply to tower, Beam Hall- I, Beam Hall -II and other associated lab areas round the clock throughout the year . In order to further increase the reliability of the Compressed air supply at constant pressure, a 25 m^3 Storage tank is added in the system. It is installed in the Compressed air line on the roof of UB II. Pneumatic connections have been extended to all the labs.

A stand by screw compressor of 115 m^3/Hr capacity is added in PH I plant in order to meet any eventuality of breakdown of existing compressor. A storage tank of 1kL is added between compressor and Air dryer for smooth flow of compressed Air.

Further to ensure low dew point of the air, the compressed air is passed through two refrigerated type air dryers of 4300 LPM capacity. Ultra high filters of boro silicate and carbon filters are provided in different location of the compressed air to provide clean air free from dust and oil particles. The filter cartridges of Ultra high filters are changed once a year to maintain the quality of supply air.

Since Reciprocating compressors which are more power consuming and source of excess oil contamination in the compressed air, is phased out.. Compressed air piping has been extended to Lab I, Lab II and New Workshop building.

ii) **Industrial Gases:** Various industrial gases required in different labs have been made available from time to time. Special gases like Iso Butane and mixture gases are also procured for labs.

iii) **Elevator:** The Elevator has been replaced of similar capacity with modern features. The new Elevator is put in to use.

iv) **Material Handling System :** Periodic maintenance / servicing of more than 14 Nos E.O.T cranes and electric hoists of various capacity varying from 1 ton to 7.5 tons are being carried out periodically and the same have been working smoothly. Two more cranes of 7.5 tons capacity in BH III and 2 tons Electrical Hoist in BH III has been added. Two heavy duty Radiation protection sliding doors of Experimental area is also added under AMC. Important area cranes are put on remote control operation for safe handling of machines.

v) **Fire Extinguishers:** Annual refilling and periodic maintenance of all the fire extinguishers have been carried out. New fire extinguishers have been installed in newly constructed BH III, store area , Lab I and Lab II area, Workshop building. Some more sign boards including the "Escape route" is added in the building which shines even in darkness. .Demonstration for use of Fire extinguishers have been arranged and all the users and IUAC employees are trained to use the fire extinguishers.

2nd Floor of Lab Building under PH II part II has been newly added. As per Fire safety norms which includes pressurized water hydrant system. It includes centralized pressurised water system connected to underground Water tank and water pumps which maintain continuous water pressure in the water hydrant line. This system is available in PH II Part II buildings. All the Labs and experimental areas have smoke detectors having display unit and sound alarm at Reception of Lab I which is attended round the clock by operator.